FOUNDRY
EST. 1902 TRADE JOURNAL
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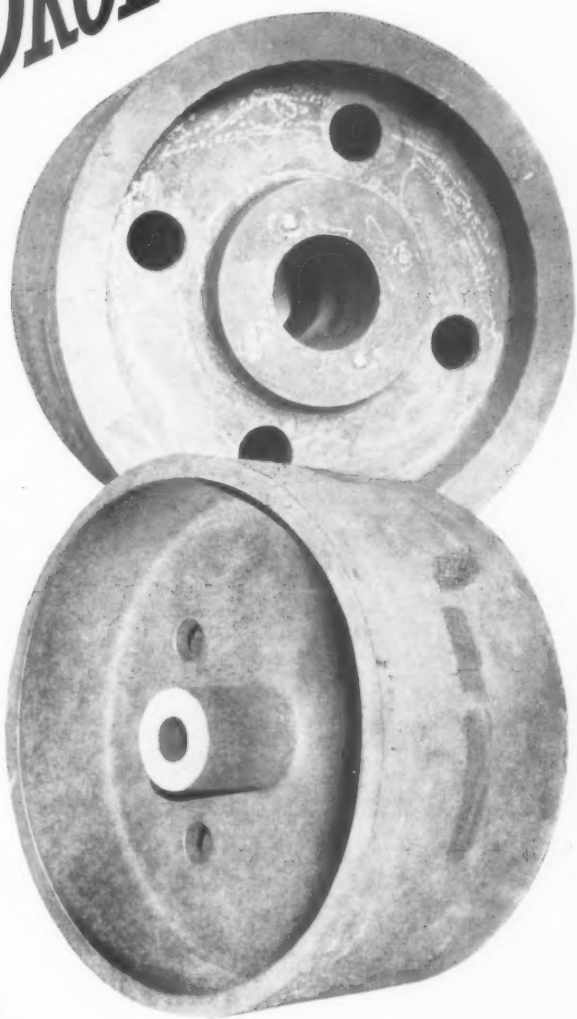

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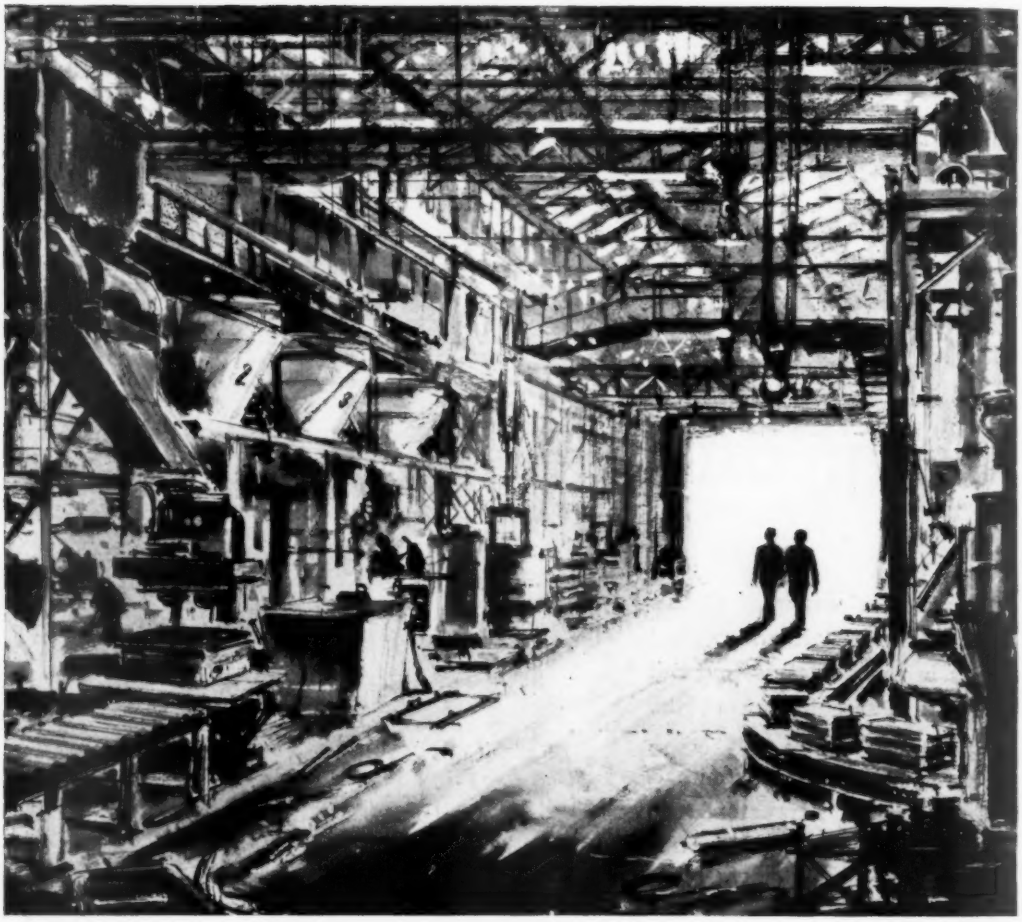

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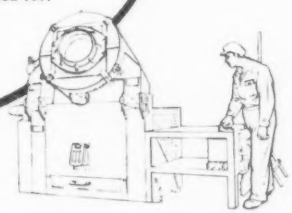

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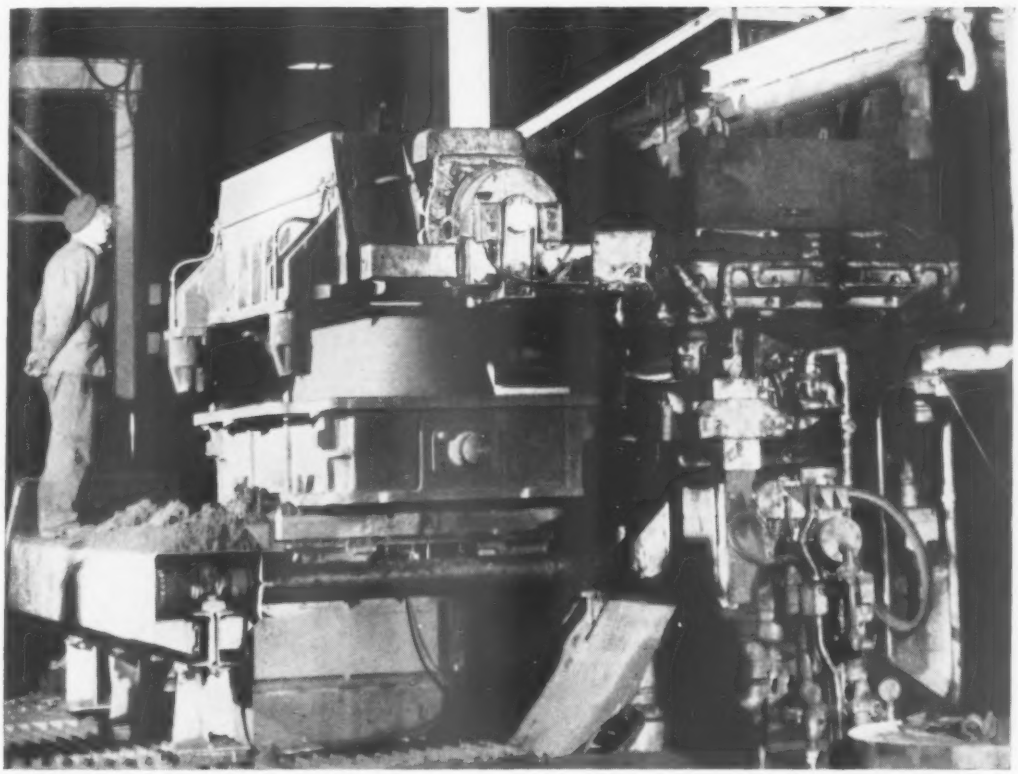

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Photograph by courtesy of British Bath Co. Ltd.

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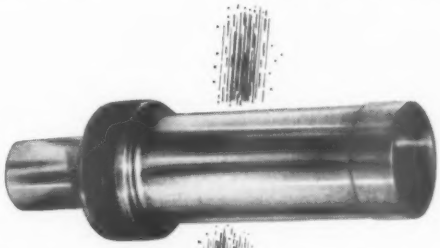

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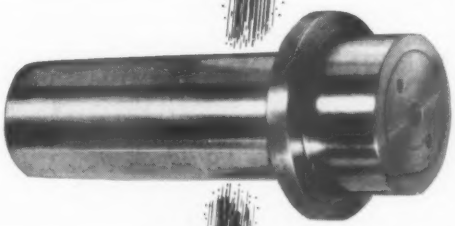

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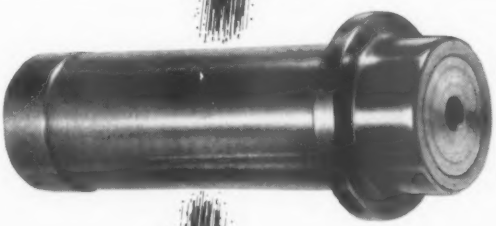

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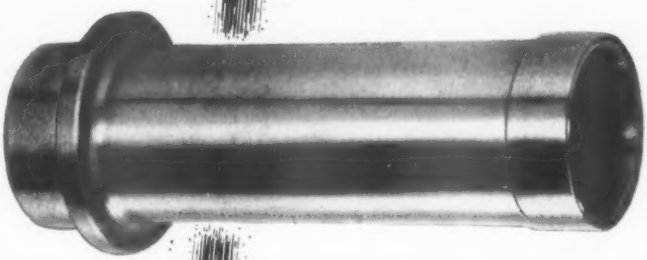

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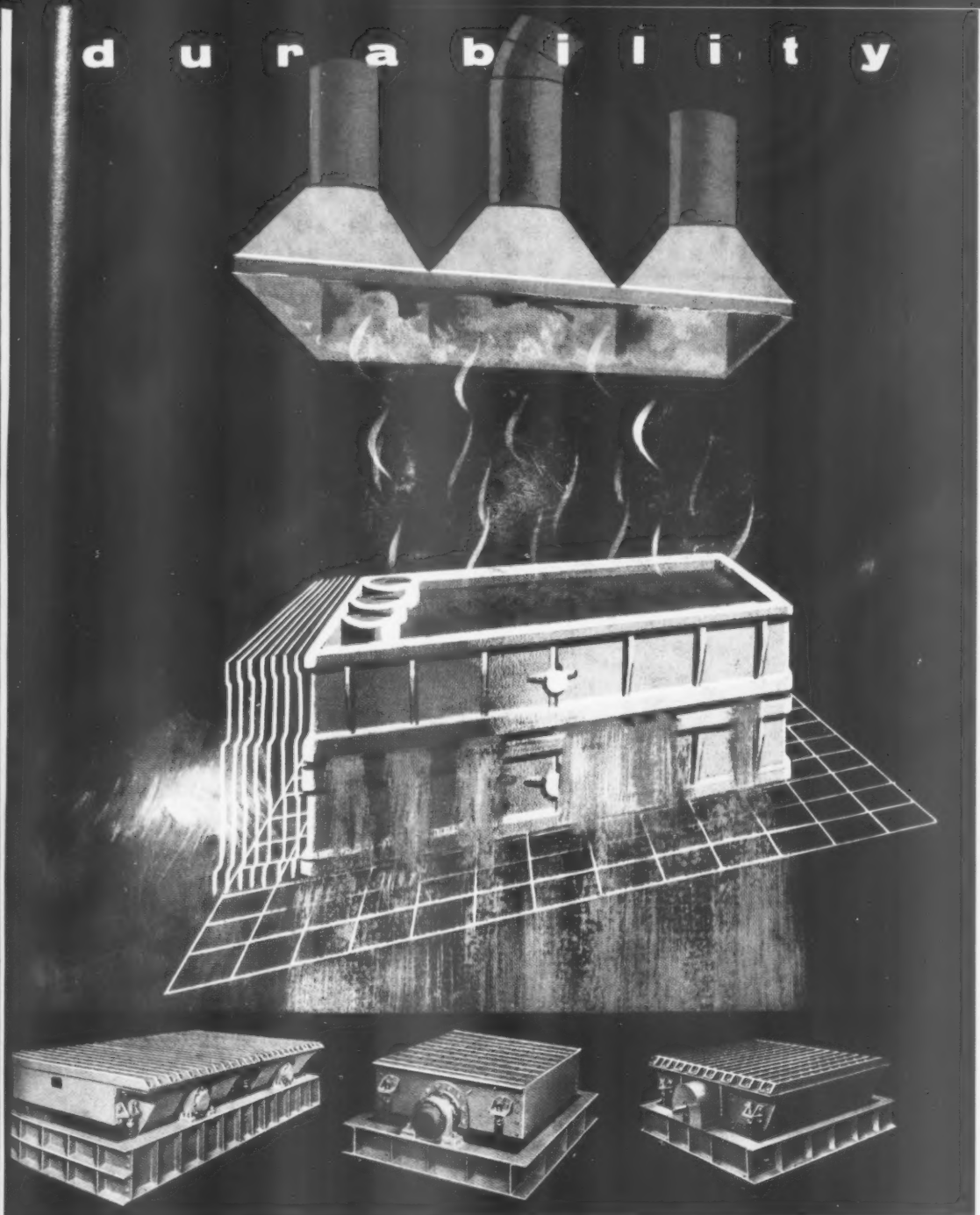

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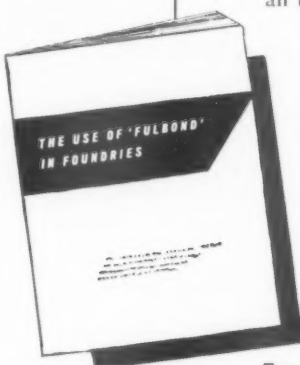

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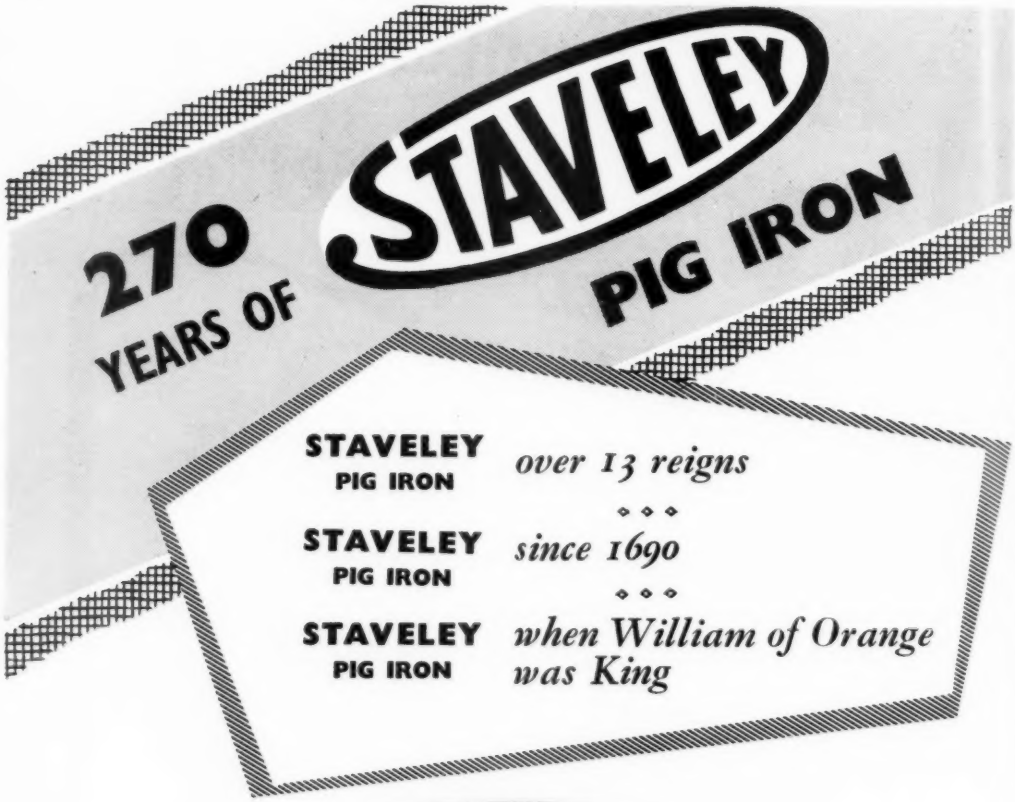

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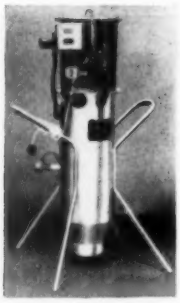

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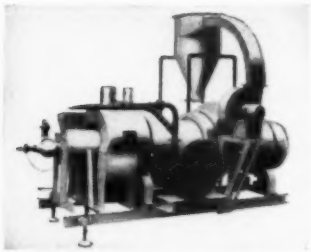
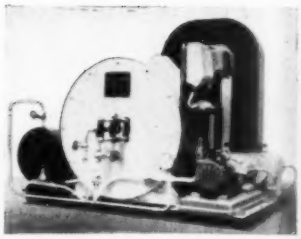
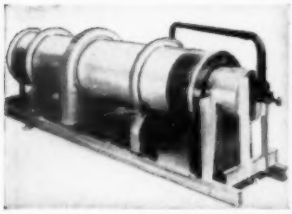


Sand Dryer and Cooler



Portable Oil Fired Mould Dryer



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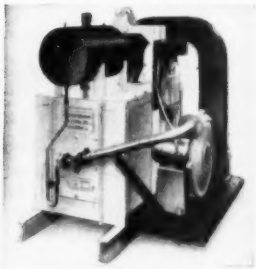

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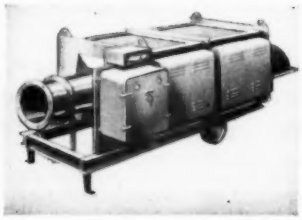

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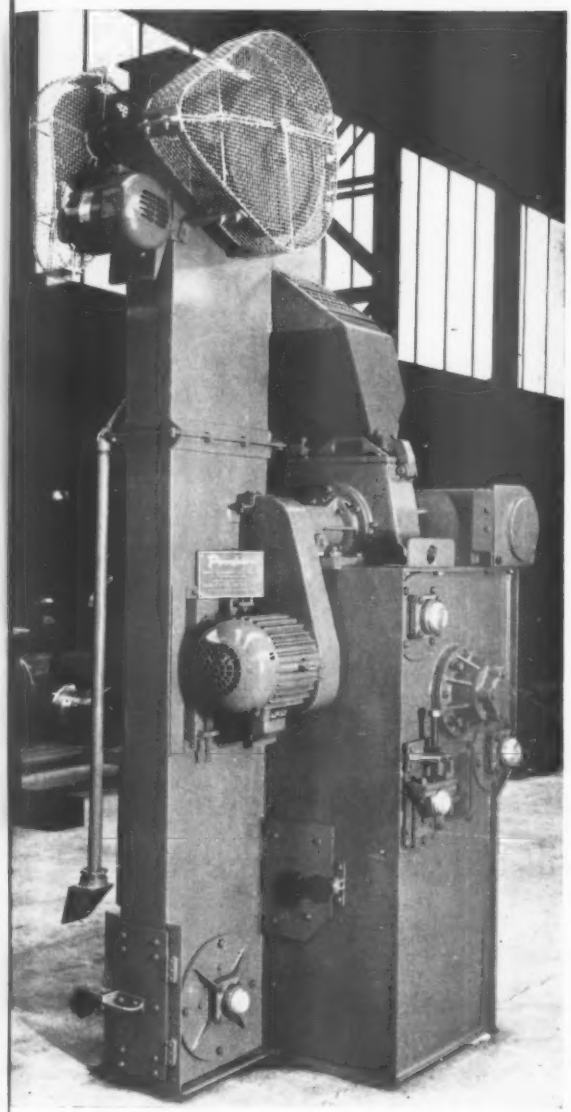

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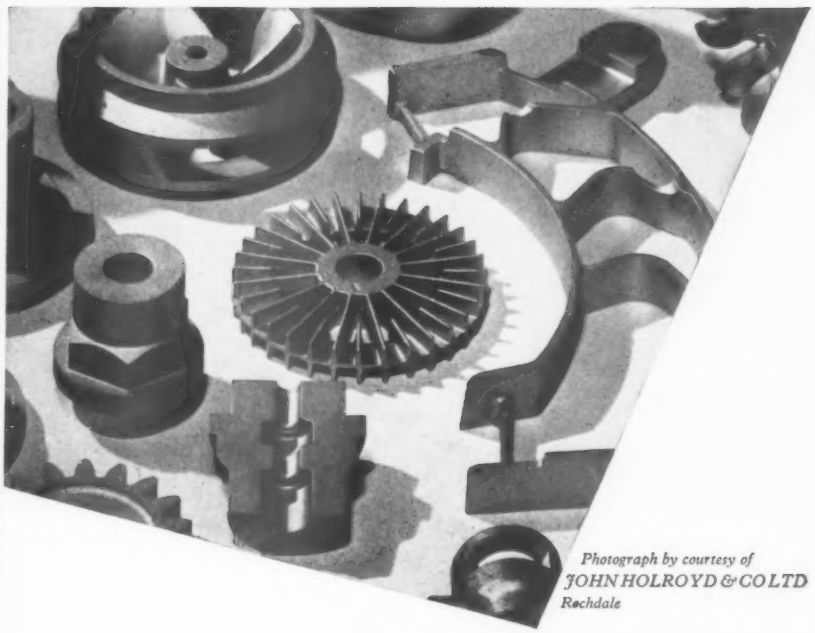

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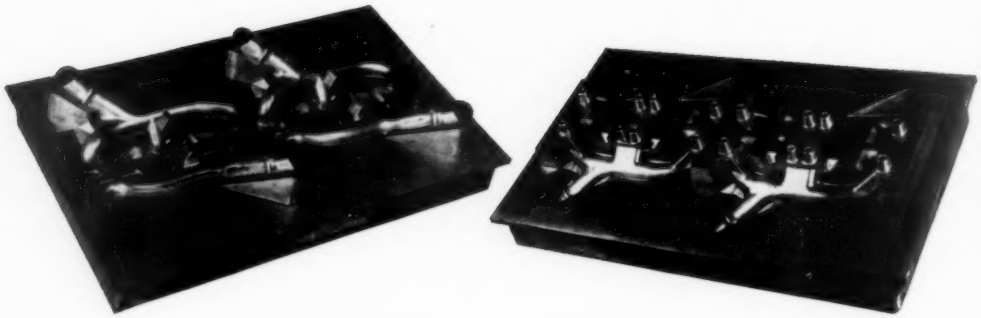

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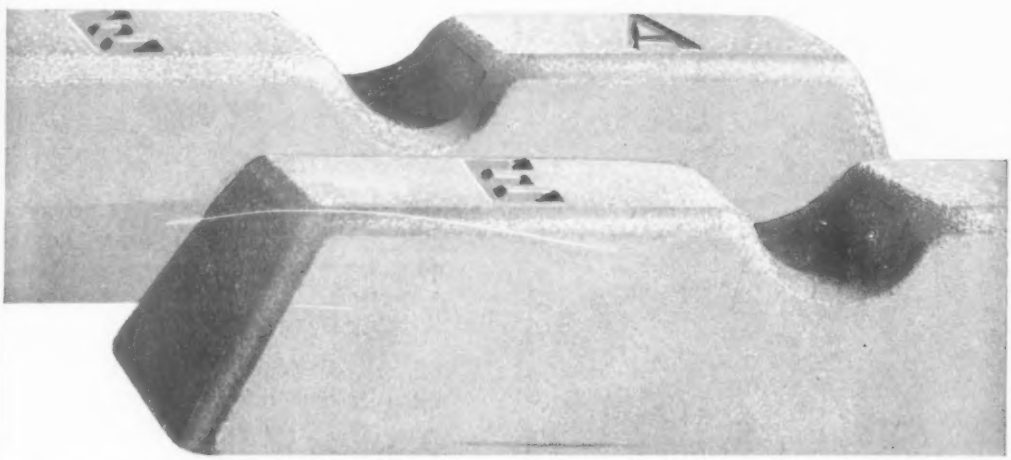

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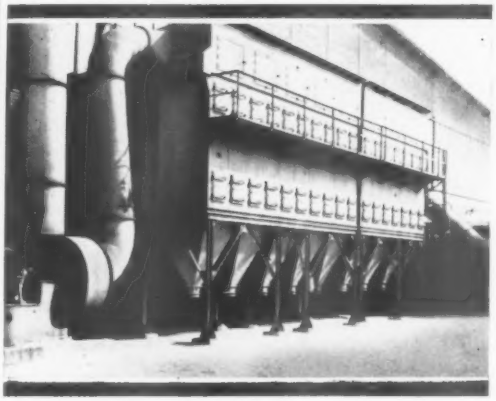

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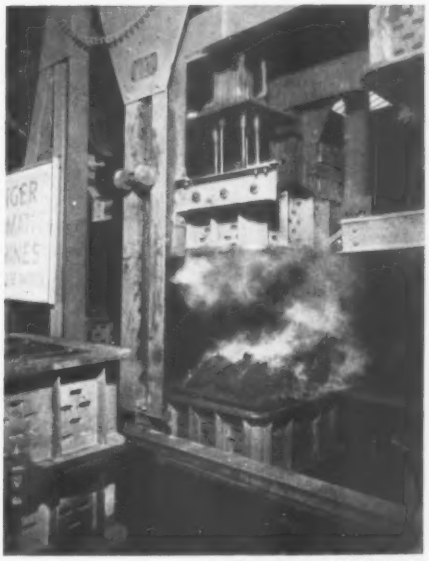

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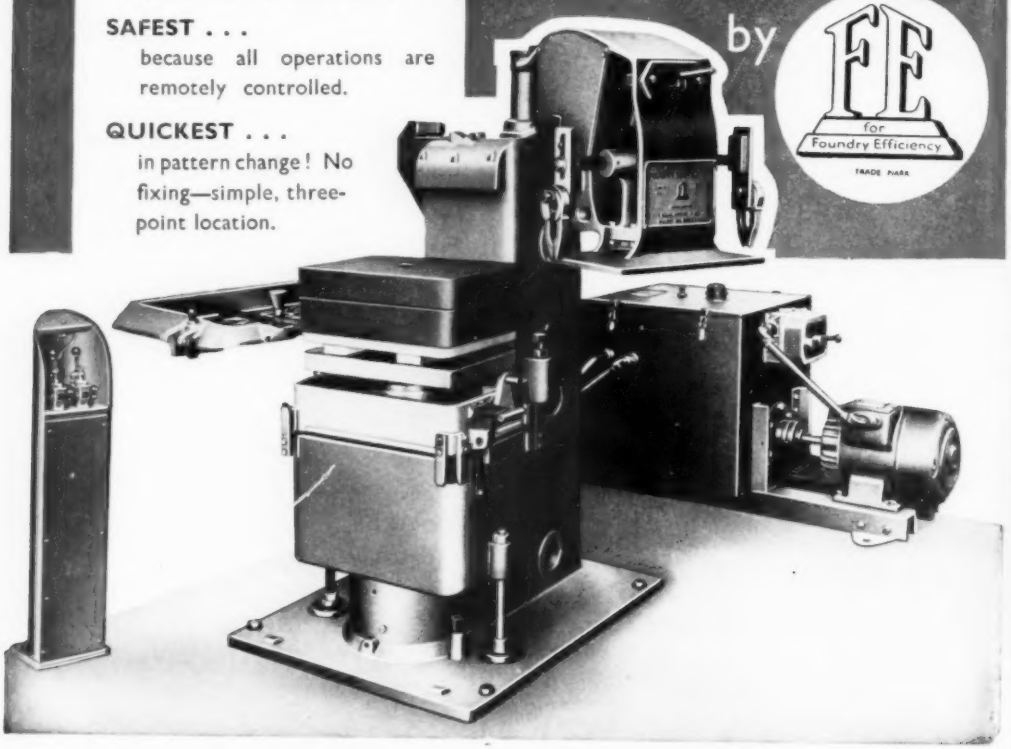

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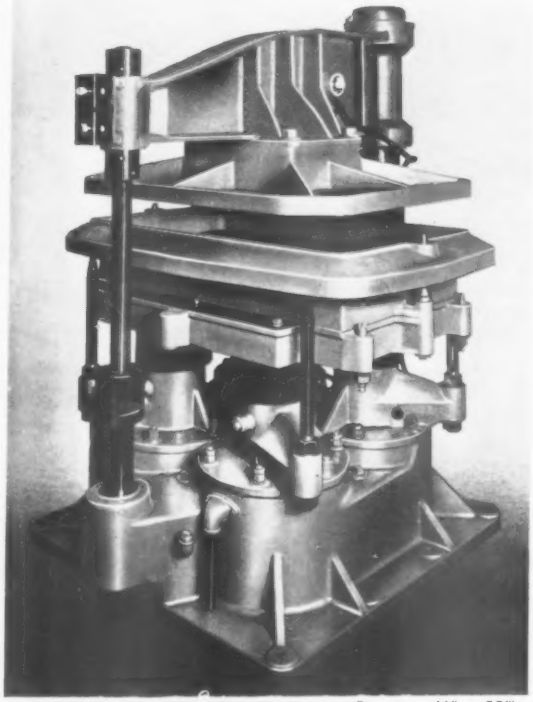

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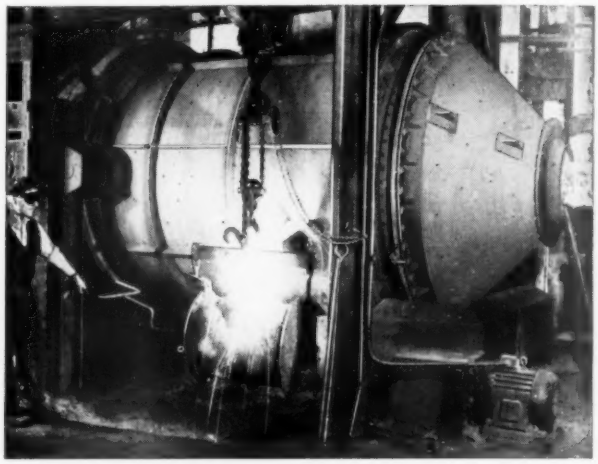

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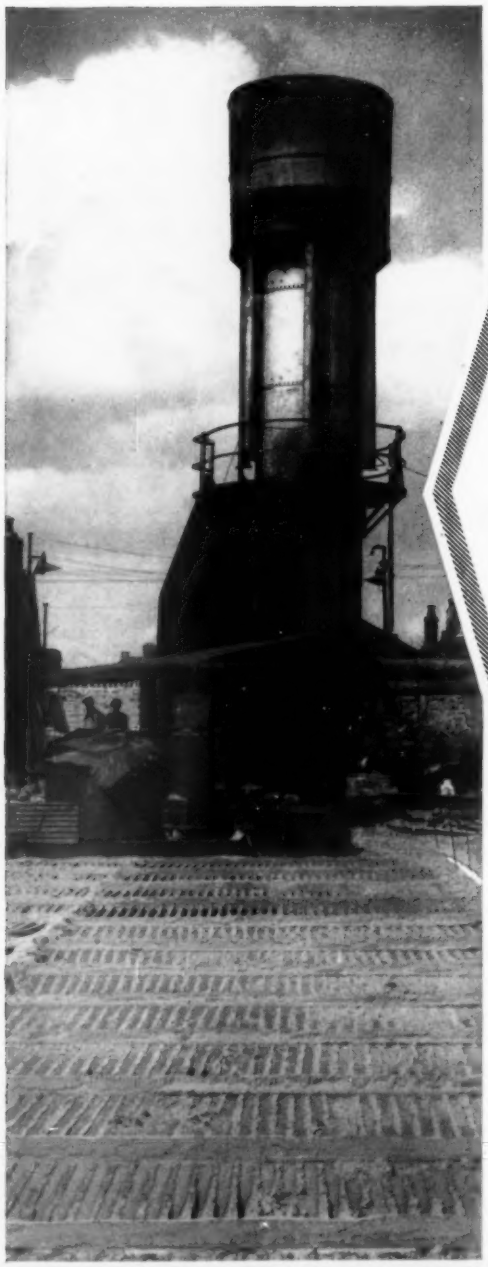

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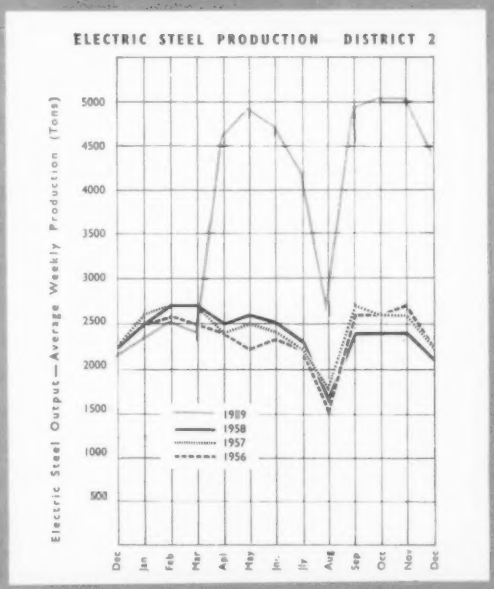

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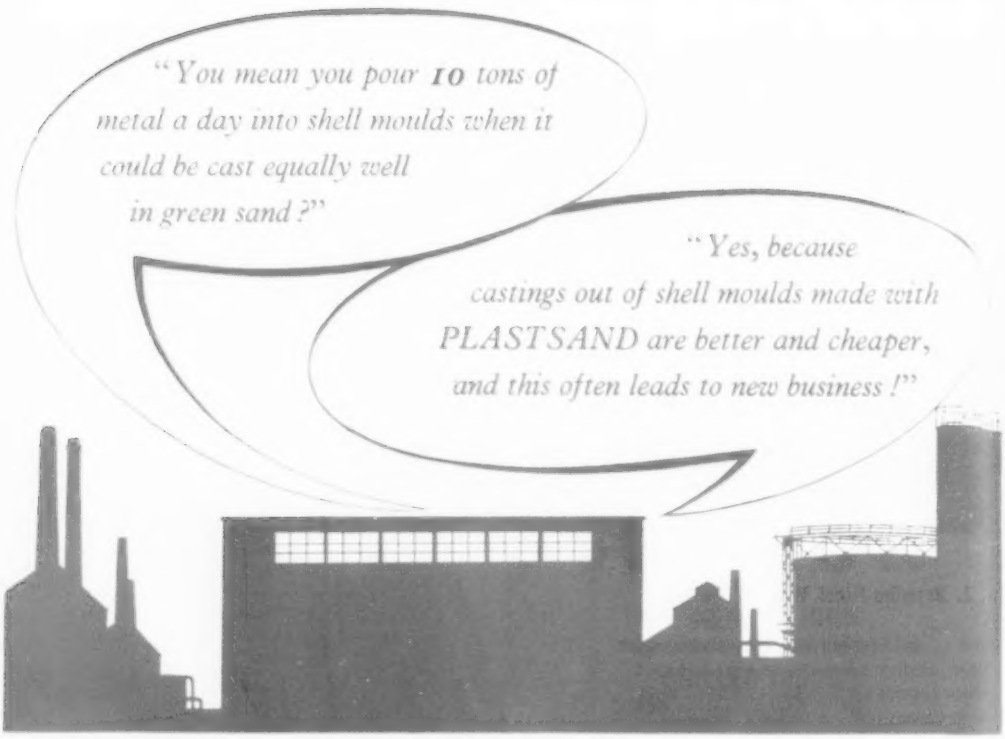
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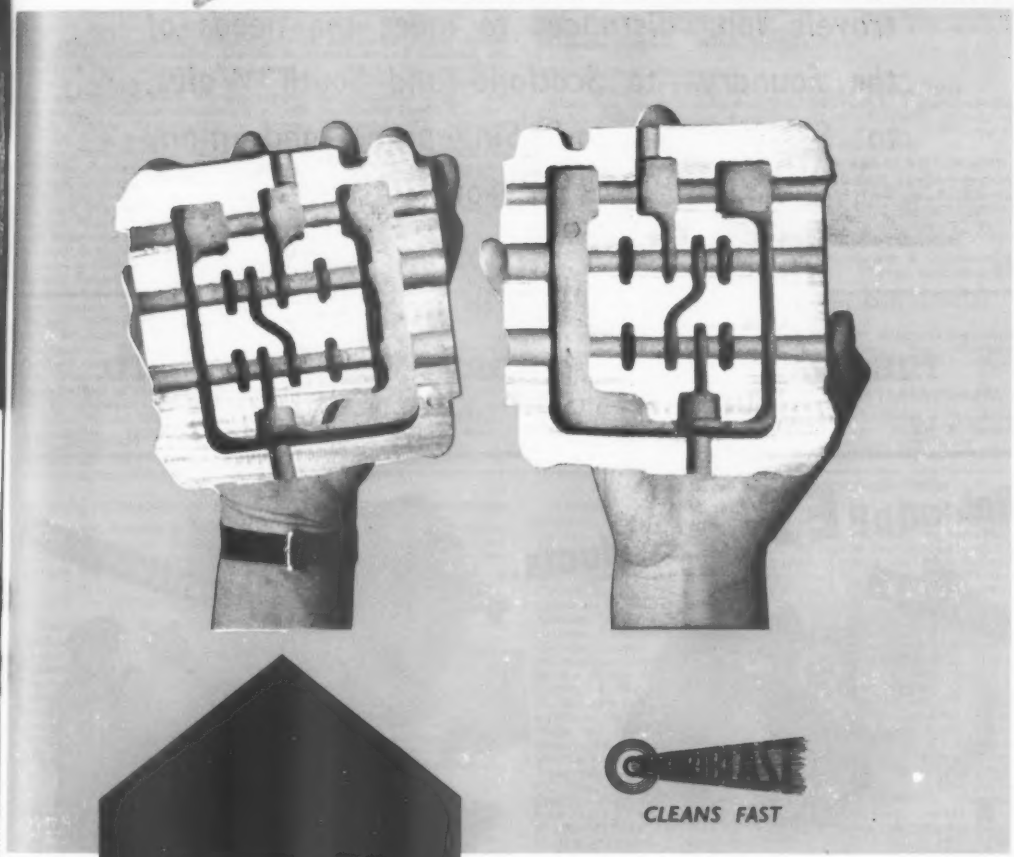

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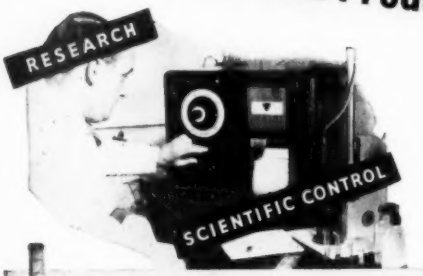

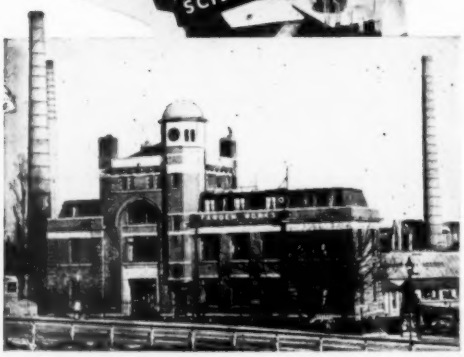

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ORGANIZATION OF THE UK FOUNDRY INDUSTRY

The foundry industry of the United Kingdom is represented by the following organizations, many of whose proceedings are regularly reported in this JOURNAL :—

Ironfounding Employers' Associations

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Chairman: **M. J. Glenny**, Dover Engineering Works, Limited, Talbot House, Arundel St., London, W.C.2. *Director:* **K. Marshall.** *Ass. Director:* **J. W. Butler,** *Secretary:* **D. L. Farrant,** 14, Pall Mall, London, S.W.1. 'Phone: WHItehall 7171. *Participating Associations:* British Cast Iron Research Association (affiliated); Institute of British Foundrymen (affiliated), and the following:—**Association of Automobile and Allied High-duty Ironfounders.** Secretaries, Heathcote and Coleman, 69, Harborne Road, Edgbaston, Birmingham, 15. 'Phone: Edgbaston 4141. 'Grams: " Clarify," Birmingham, 15. **British Ironfounders' Association and British Bath Manufacturers' Association.** Director and Secretary: J. Galbraith Sneddon, C.A., 145, St. Vincent Street, Glasgow, C.2. 'Phone: Central 2891. 'Grams: " Groundwork," Glasgow. **British Grit Association** (affiliated).—Secretary: J. Campbell MacGregor, 10, Bank Street, Airdrie, Lanarkshire. **British Malleable Tube Fittings Association.**—Secretary: F. B. Ridgwell, 196, Shaftesbury Avenue, London, W.C.2. 'Phone: TEMple Bar 6052-3. 'Grams: " Brimatufia," London. **Cast-Iron Chair Association.**—Secretaries: Peat, Marwick, Mitchell & Co., The Cast Iron Chair Association, Queen's Square, Middlesbrough, Yorkshire. **Cast Iron Axlebox Association and National Ingot Mould Association.**—Secretaries: Peat, Marwick, Mitchell & Company, 301, Glossop Road, Sheffield. 'Phone and 'Grams: Broomhill 63031. **Cast Iron Heating Boiler and Radiator Manufacturers' Association.**—Secretary: Stanley Henderson, 69, Cannon Street, London, E.C.4. 'Phone: CITy 4444. **British Cast Iron Pressure Pipe Association.**—Secretary: W. I. Campbell, 14, Pall Mall, London, S.W.1. 'Phone: WHItehall 7941. **Cast Iron Segment Association.**—Secretary: W. Rose, Stanton Ironworks Company, Limited, P.O. Box 3, near Nottingham. **Greensand Pipe Founders' Association.**—Secretaries: McClure Naismith Brodie & Company, 77, St. Vincent Street, Glasgow, C.2. 'Phone: Glasgow 9476. 'Grams: "Lycidasm," Glasgow. **National Association of Malleable Ironfounders.**—Secretary: Miss L. Verity, M.B.E., Chamber of Commerce Offices, Tudor House, Bridge Street, Walsall. 'Phone: Walsall 5671. **National and Midland Ironfounders' Association.**—Secretary: F. W. Sims, 69, Harborne Road, Edgbaston, Birmingham. 15. **Roll Makers Association of Great Britain.**—Secretaries: Peat, Marwick, Mitchell & Company, Beaufort House, Newhall Street, Birmingham, 3. 'Phone: Central 6661-3.

NATIONAL FEDERATION OF ENGINEERING & GENERAL IRONFOUNDERS

Chairman: **Francis D. Drake,** Drakes (Engineers), Limited, Ovendon, Halifax. *Secretaries:* **Mann, Judd & Co.,** 8, Fredericks Place, London, E.C.2. **Constituent Associations:** Ironfounders' National Confederation and National Ironfounding Employers' Federation.

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Chairman: **F. D. Drake,** Drakes (Engineers), Limited, Ovenden, Halifax. Secretaries: **H. Overton, Salt & Company,** 12th Floor, City Centre House, 30, Union Street, Birmingham, 2. 'Phone: Midland 8427. **Branch Associations:** *East and West Ridings.*—Secretary: C. L. Carver, Ellerby Foundry, Ltd., Ellerby Lane, Leeds, 9. *London, Home and Eastern Counties.*—Secretaries: H. Overton, Salt & Company, 30, Union Street, Birmingham, 2. *Midlands.*—Secretary: V. L. Nicholls, Grazebrook Foundry Limited, Blower's Green, nr. Dudley, Worcs. 'Phone: Dudley 52431 *North Midlands:*—Secretary: C. W. Hicks. Rolls-Royce, Limited, Nightingale Road, Derby. 'Phone : Derby 42424. *North Western.*—Secretary: D. Swain, H. Overton, Salt & Company, 30, Union Street Birmingham.

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Other Employers' Associations:

BRITISH STEEL FOUNDERS' ASSOCIATION

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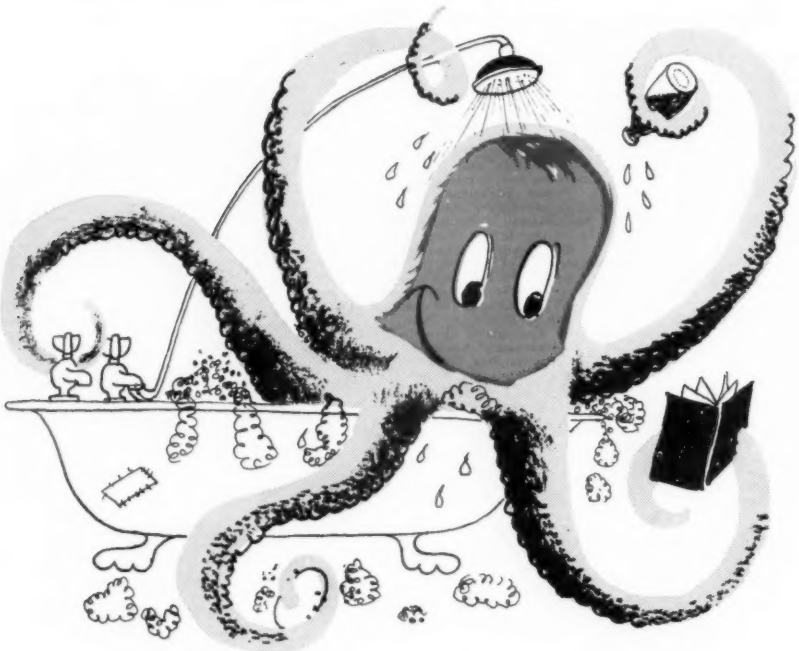

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FOUNDRY
TRADE JOURNAL

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The Small Manufacturer and Exports

The appeal of the Prime Minister to the small manufacturer to increase his efforts to export more of his production has had the good result of making this class of manufacturer think more seriously about the subject. There has been a plethora of correspondence in the daily Press stressing the difficulties attendant on form-filling for export business, the establishing of credit facilities and the requisite time for travelling. Letters have been sent by trade associations to the Board of Trade, suggesting what are deemed to be necessary improvements. Usually, they stress the difficulties experienced by their smaller members in financing export orders.

Form-filling—a routine task for the larger concerns—is not easy for firms inexperienced in export and it is wise to employ reliable shipping agents. We remember what is now a huge concern losing (when quite a small firm) a large consignment of goods by failure to attend to the most important of all documents—the mate's clearance. It would be best for some of the trade associations to act as advisory bodies in the matter of exports for their inexperienced members, even though this step involved creating a separate company to handle such business. This has actually happened in the case of the patternmaking trade, where a number of its members formed a separate company to handle export business. Though but recently established, early results are promising; the manufacturing facilities have been greatly extended, and such matters as form-filling, credits and translation services being centralized, have become less onerous.

The major worry for the owner of a small factory will always be the financing of overseas orders, as the under-developed countries are demanding excessively long periods of credit—up to ten years has been quoted in some cases. Presuming the business to be important and worth while in the national economy, surely such questions should be handled by the Board of Trade which has knowledge of the conditions accorded by overseas competitors. No private enterprise, especially the smaller ones, should be called upon to undertake such long-term finance, especially to countries that have been unstable politically over the last five decades. The larger firms should and can help the smaller ones in this very difficult question of overseas selling.

Pneumoconiosis—a "Pilot" Survey*

Pneumoconiosis is an occupational disease caused by the inhalation and retention within the lung of minute particles of mineral dust which damage the tissues of the lung. There are several varieties of the disease arising from the many occupations in which it may be contracted. Among these occupations and processes, some of the principal are coal-mining; the mining and quarrying of many rocks and minerals; china, earthenware and refractory manufacture; foundrywork; asbestos manufacture; masonry and slate making; boiler scaling and coal trimming; and operations involving sand-blasting or the use of grinding stones. At the present time in England and Wales some 43,000 people draw pensions because they suffer from some degree of physical disablement as a result of having contracted the disease. In 1958, the Registrar General issued 2,373 death certificates recording fibrosis of the lung, including 74 certificates in respect of foundry pneumoconiosis, 37 of these latter were specified as ironfoundry pneumoconiosis.

Information on the disease as it occurs in iron foundries is limited, and it has been difficult to compare and correlate the knowledge gained from different sources. Moreover, the greater part of the known information refers to the experience of a relatively small number of the larger iron foundries. In an attempt to gain an appreciation of the extent and nature of the risk in the smaller iron foundry, the Council of Ironfoundry Associations has carried out a survey† in 44 foundries in Scotland, the Midlands and N.E. and N.W. England, examining altogether 1,437 volunteers (about 88 per cent. of their labour force). The results obtained have been more reassuring than many had feared. However, they give no ground for complacency, but will serve to encourage the industry in its efforts to control the dust causing the disease.

No clinical examinations were made because it was feared that these might have deterred men from co-operating in the survey, and because of the loss of working time that would have been involved. This factor must qualify the accuracy of the findings in the case of the individual man, since a clinical examination is needed for any firm diagnosis of pneumoconiosis. However, a chest radiograph and details of occupation and health histories were taken in respect of each man. These details, when taken together, have allowed general conclusions to be drawn—bearing in mind that an abnormal pattern on the radiograph of a worker exposed for years to the inhalation of dust during work is likely to be produced by retention of dust in the lungs, probably associated with the formation of fibrosis or scar tissue.

As a result of the examinations, 1,338 men were informed that their radiograph showed no significant abnormality. Sixty-eight men were advised to consult their doctors on the grounds that their radiograph, and other information supplied by them, appeared to indicate an occupational chest-condition warranting further examination. At least 19 of these men have since been examined by Ministry of Pensions and National Insurance pneumoconiosis medical panels, and 10 have been awarded pensions in respect of some degree of disablement.

Of the 1,437 radiographs taken, 41 (2.9 per cent.) showed lung changes suggesting marked dust-retention, 282 (19.6 per cent.) showed changes suggesting moderate dust-retention and 747 (52 per cent.) showed changes suggesting slight dust-retention. Evidence was found, however, that the factor of age was of no less importance than length of exposure to occupational dust when assessing the causative factors of X-ray change. No striking difference was found in the incidence of lung change as between any one of the four geographical areas and another.

* See also "Ironfounding Health and Safety"—report of a conference organized by the Council of Ironfoundry Associations, JOURNAL, April 21 and 28, May 26, and July 14.

† "Pneumoconiosis Survey" published by the CFA from 14, Pall Mall, London, S.W.1.

"Selling Capital Goods"

An opportunity to discuss the vital question of exports will be provided at British Institute of Management conference on "Selling Capital Goods," to be held in Harrogate from November 16 to 18.

The export of capital goods to under-developed countries, overseas competition, the effect of the European Common Market on exports and restrictive practices in the export market will be discussed in the opening paper by Dr. J. G. Mackay (managing director, Francis Shaw & Company, Limited, and chairman, Rustyfa, Limited). Other papers will cover such subjects as "Overseas Sales and Service"; technical innovations in production matched to customer needs and the question of how British manufacturers compare in this respect with those overseas; "Development of Selling Ability"; "Long-term Repayment as an Aid to Selling"; "Role of Advertising in Selling Capital Goods"; "Public Relations"; and "Market Survey Work in Light and Heavy Capital Goods." Sir Leslie Robinson, K.B.E., C.B., of the Board of Trade will give the closing address at a dinner to be held on November 18.

Shipbuilders' £570,000,000 Order Book

The Shipbuilding Conference states that in the second quarter of 1960 British shipbuilders secured contracts for 85 ships of 185,000 tons gross, which brought total orders for the first half of the year to 138 ships of 353,000 tons gross. This compares with 29 ships of 44,000 tons gross ordered in the second quarter of 1959, and 82 ships of 98,000 tons gross during the first half of that year.

At the end of June, 1960, the industry's total order-book stood at 466 ships of 3,780,000 tons gross, of which 61 ships of 731,000 tons gross, of 19.3 per cent., were for foreign owners. The estimated current value of the total order-book is £570,000,000. Improvement in the flow of new work towards the end of 1959 continued until May this year, the conference states, but experience in June, when orders for only 25 ships of just over 20,000 tons were placed and contracts for seven ships were cancelled, was a reminder that prospects for the industry remain uncertain.

Beryllium Plant sold by UK Atomic Energy Authority

Beryllium works of the United Kingdom Atomic Energy Authority at Milford Haven has been sold to Consolidated Beryllium, Limited, which is managed by the Imperial Smelting Corporation—a wholly-owned subsidiary of the Consolidated Zinc Corporation.

The works have been operated on an agency basis by Murex, Limited, and operations are now to be continued by Consolidated Beryllium on a reduced scale.

IBF Fifty-seventh Annual Conference

Concluding Survey of Technical Sessions at the recent Malvern Meeting with Notes on Pertinent Matters arising in Discussion of Some of the Papers.

An earlier report* included the majority of papers presented during the Wednesday technical sessions of the Institute of British Foundrymen's Conference at Malvern last month and the following abstracts complete the survey of the Wednesday proceedings and then take in the technical contributions given on the Friday. On all occasions, simultaneous sessions were held, one in the Festival Theatre and the other at Priory Lodge Hall of the Winter Gardens:—

Aluminium-alloy Side-scuttles for Ships

By E. Elliott, A.Met., F.I.M.

Continuing the series on light metals, in this paper, the Author (who is chief metallurgist of the ADA) gave a brief account of the nature and functions of ships' side-scuttles and of the properties of aluminium alloys which made them attractive for this application. Design features and precautions to be observed in installation and service were discussed and tests on aluminium-alloy scuttles over the past few years were summarized. The Author said the tests had led to the acceptance of these items by inspecting authorities under certain conditions—which were quoted—and possible future applications were touched upon.

The Author in describing the functions of ships' side-scuttles said these components consisted of three cast parts, namely, the main frame (an annulus of metal which was bolted to the ship's plating), a glass holder (an annular metal frame for the glass —this might be of opening or non-opening type), and the deadlight (a circular piece of metal which was hinged to the main frame at one side and might be screwed down around its periphery to close the opening completely from the inside of the ship). Passing on to the choice of alloy for these items, the Author described investigatory work carried out with alloys LM5-M, LM6-M and LM10-W, to the BS. 1490 specification. In view of the variety of types of side-scuttle and the relatively small numbers of each type required, the principal method of production was sand casting, although gravity-die-casting should not be excluded as a future possibility.

Experimental Work

When consideration was first given (about a decade ago) to the testing of aluminium-alloy side-scuttles, the Ministry of Transport had stated as tentative requirements that the alloy used should provide, on separately-cast bars, a tensile strength of not less than 10 tons per sq. in., with an elongation on a 2-in. gauge-length not less than 7 per cent. Additionally, it was required that sample deadlights should be bent around a bar of 2-in. radius to an angle of not less than 40 deg. without fracture—a test originally designed for side-scuttles in malleable iron. During the period 1951-7, a large number of tests of aluminium-alloy side scuttles had been made and in his paper, the Author included some representative examples. In addition to the requirements of BS. 1490, the two main tests which had been applied to aluminium side-scuttles were the bending of deadlights and the dropping of deadlights, main frames, and glass-holders on to iron or concrete, the height of drop being 10 ft. for frames and 15 ft. for deadlights.

Experience with aluminium side-scuttles was expected to lead to their wider acceptance and it was hoped that this would result in the eventual removal of the more-restrictive requirements, notably, for example, the limitation of application at present to positions not below the bulkhead deck in passenger ships or below the freeboard deck in any ship.

Solidification of Cast Iron and the Interpretation of Results obtained from Chilled Test-pieces

By H. Morrogh (director, BCIRA)

The Author stated initially in this paper that, the properties, structure and chilling characteristics of grey cast iron were largely determined by the way in which the eutectic constituent solidified; that solidification of the eutectic involved nucleation and growth, and the number of nuclei growing and their growth rate from a given melt increased with the amount of undercooling, which in turn increased with increase in cooling rate. In the paper, the effects of variations in these factors were discussed, with reference to hypothetical cooling curves. Within each grey-iron eutectic cell, there could be visualized a continuously branching skeleton of graphite, the frequency of branching depending on the radial-growth rate. Appropriate etching could be made to reveal the eutectic-cell structure and by counting the number of eutectic cells, the number growing and the nucleation of a melt could be quantitatively assessed. Summarizing, Mr. Morrogh said a reduction in pouring temperature or in section-size increased the number of eutectic cells, by increasing the cooling rate. The nucleation of a melt was also reduced by holding, by superheating, or by agita-

* See JOURNAL, July 21, p. 83.

tion before pouring. Inoculation increased nucleation; increasing sulphur content also increased nucleation of the melt and reduced the growth rate of the eutectic cells. Phosphorus increased the number of eutectic cells growing.

The solidification of the white-iron eutectic took place either in a ledeburitic or in a plate-like manner. Thermal considerations involved in the solidification of simple chilled test-pieces cast in sand moulds against chillers involved the interplay of two cooling rates, one due to the chiller and the other to the sand mould. Simple diagrams could be prepared, which enabled the effects of variations in pouring temperature and test-piece size to be explained. These variables, Mr. Morrogh went on, had opposite effects according to the graphitizing potential of the iron. The effects of factors influencing the nucleation and growth-rate of graphite eutectic were discussed in relation to the thermal factors influencing chill depth and mottle spread.

In his paper, the Author had attempted to describe some of the thermal factors involved in the solidification of chilled test-pieces and to show that it was necessary to take account of the cooling effect of the chiller and the sand mould used. If this concept were adopted, it was possible to explain the effect of pouring temperature and test-piece size and to relate many of the factors influencing the solidification of grey cast iron to the appearance of the chill and mottle in chilled test-pieces. Much further research remained to be carried out, Mr. Morrogh concluded, but a beginning had been made in this work which might lead to a more comprehensive and rational understanding of the factors relating chill depth in a chilled test-piece to that in a larger chilled casting.

Discussion

Before the discussion was opened (with Mr. G. R. Shotton in the chair), Mr. Morrogh explained that the above represented the work of a number of colleagues. It was designed to help in the production of chilled castings—instead of the avoidance of chill (to which, so often, the efforts of the Association were directed). It had resulted in the development of a particular type of test-piece in use in the rollmaking industry and the research had explained a number of past anomalies in relation to roll material.

The first questioner to open the discussion asked why the term "under-cooling" was used instead of "super-cooling" and what was the effect of self-annealing due to mould material raised to red heat by the metal. On the first point, Mr. Morrogh said that under-cooling was a better term than super-cooling because it more nearly expressed the idea of cooling below the solidus; self-annealing was a minor effect which did not vitiate the general results which had been reported and could in fact be explained by them.

"A Spanner thrown in the Works"

The next questioner was in complete variance with Mr. Morrogh's findings on a number of points, saying that in examining the whole idea of solidification, the theories of nucleation seemed to be regarded as basic data, but it was admitted that little was known about these phenomena. Thus, to interpret a series of observations in terms of nucleation and growth became a matter of speculation and, as usual in such cases, alternative speculations were possible. For example, using the anomaly of Al/Si alloys, the cast structure could be expressed directly in terms of the actual solidification temperature and cooling rate. A second point, the same speaker raised, was about the occurrence of mottle at the chill face itself. He said that this too could be a temperature effect. To these points the Author replied that it was quite legitimate to introduce theories to explain facts and the more substantiation which was obtained from time to time for the theories the more likely it was that they were correct and this was really the situation with regard to the nucleation theory. Mottling, too, could be expressed directly in terms of cooling gradient adjacent to the metal/chill interface.

Other questions at the same session, all of which were satisfactorily answered by the lecturer, included a request for information as to which phases were nucleated if any and the effect of pouring temperature on depth of chill. To an inquirer who wished to know how to chill one face only of a cast-iron slab 36 by 18 by 2-in. thick, Mr. Morrogh prefaced his reply by saying that he would prefer not to have to do this! He explained that though difficult it was feasible by applying practical measures to secure the correct cooling rate in the manner discussed in the paper.

"Striking Back"

Asked if the case of a chill striking back into a casting from a "fin" was an obvious extension of the work described, the lecturer thought that it was, but when posed with the question why such striking back should be more serious with a hematite type of iron, he said that he didn't see why this should be unless it was that, in high-phosphorus irons, the phosphorus helped to nucleate. Final questions about the effect of oxygen and trace-elements, graphite structure and inverse chill were grouped together in the lecturer's reply which stated that both gas content and trace elements were to be regarded as part of composition effects and these had been stated in the paper to be of definite significance. However, the programme of investigations of the possible effect of elements present in iron in quite major quantities was not yet completed and more research was needed. The "cabbage-like" structure of graphite had in fact been proved without any shadow of doubt by separation chemically of "cabbages" from solid iron. The phenomenon of inverse chill could be explained, he concluded, by applying the ideas of the paper, *i.e.*, the rate of solidification in relation to composition—and the sulphur content in particular.

Pearlitic Malleable Iron

By C. F. Joseph

The conference contribution " Pearlitic Malleable Iron " was a sponsored paper from the American Foundrymen's Society (the Author being technical director of the central foundry division of General Motors Corporation, Saginaw, Michigan). It was in the nature of a survey of pearlitic malleable iron as an engineering material and the Author discussed the properties of the material and considered its future prospects. He showed that pearlitic malleable iron had outstanding advantages over a number of other materials.

History

In his introduction, the Author stated that in 1938, about 300 tons of pearlitic malleable iron was consumed by the automobile industry in the USA, but to-day, the total production was more than 200,000 tons per year. The continuing rapid growth in acceptance and use of pearlitic malleable iron in the USA was largely because producers were stressing uniformity and providing castings with properties necessary for satisfactory performance of components in service. Information furnished by the Council of Ironfoundry Associations in the UK showed total despatches in 1958 of malleable iron castings of 161,000 long tons. Of this quantity, only 14,000 long tons were pearlitic malleable iron, *i.e.*, less than 10 per cent. of the total malleable-iron production. This, the Author said, indicated great scope for British malleable ironfounders to find increasing uses for the pearlitic grade of material.

Production Control

Dealing with the production of pearlitic malleable, Mr. Joseph said that this started with the same base metal as that used for making ordinary (blackheart) malleable iron. By far the larger proportion of tonnage produced in the US was melted by a duplex process (using cupola/air furnaces or cupola/electric-arc furnaces), and this process was then described in detail. The following sections of the paper dealt with casting design, machinability of pearlitic malleable, hardenability, wear-resistance, yield strength and quality control.

In his concluding remarks, the Author visualized a future in which many foundries were producing pearlitic malleable castings for even the most critical of engineering applications. The use of electronics and radioactive isotopes was rapidly expanding in the castings industry, he said, and it was believed that the use of these techniques would result in a major break-through in increasing the pearlitic malleable-iron tonnage in critical castings in those industries requiring the highest-quality castings. Malleable-iron founders, he went on, were continuing their research and development work on new materials. Experiments with as-cast pearlitic malleable iron were being watched with considerable interest and could be expected to result in the development of a commercial material.

The tremendous growth in the use of pearlitic malleable during the last 20 years was an indication of its acceptance by industry as a reliable engineering material, and many conversions from steel forgings, stampings and weldments had been and were constantly being made, at considerable savings per part, the Author concluded.

Discussion

In remarks at Malvern which preceded the discussion on his paper, Mr. Joseph stated that his contribution could really be summed up as dealing with the automatic production of components in pearlitic-malleable material, within definite size and weight limits. In this matter, the American industry was making headway in the castings *versus* forgings battle as, for example, with crankshafts and connecting rods. Despite the possible lower strength of the casting, there was very much lower notch-sensitivity and thus a far-less-critical degree of finish was required of castings than forgings. The inspection methods he had recorded in the paper were—he hoped the audience would agree—some of them quite out of the ordinary. He visualized further applications of the material as increased production-control made possible better and better properties, but there was no doubt in anyone's mind that pearlitic malleable was now an accepted engineering material in the States.

Points of Detail

A double-barrelled question initiated the discussion, (*a*) as to whether there was any danger in air-quenching pearlitic malleable from too high a temperature and (*b*) was there any trouble in the US from contamination of steel scrap with chromium. The reply to the first was that the air-quenching was not drastic and did in fact stop distortion of castings. To the second point, the Author replied that the steel scrap was available in baled-sheet bundles comprising automobile sheet material, mainly arising in their own factories and therefore alloy free, but there could be trouble from the accidental inclusion of the odd bit of stainless steel. Bundled steel was used to the extent of 20 to 30 per cent. of the charge, the rest being of structural-steel scrap, which was carefully watched for both chromium and molybdenum content. Boron to the amount of 0.001 per cent. had been added to counter the presence of chromium and was in fact now being increased to 0.003—three times as much!

Another malleable founder contributing to the discussion said that statistics in this country showed a production of about 100,000 tons of blackheart, 52,000 tons of whiteheart and 14,600 tons of pearlitic malleable iron annually, thus the UK would seem not to be so far behind the US in the total percentage of pearlitic material. He asked could the number of specifications for malleable be reduced; were the very high proof-stresses quoted for the American pearlitic material really necessary, and did the US producer get adequate monetary return for all his efforts with this material. The replies were that the European production of

whiteheart malleable confused the statistical comparison, but the Author was of the opinion that on the Continent whiteheart was losing ground and might only continue to be produced for weldable applications. As to specifications, there seemed to be always a need for good, better and best grades, but in the Author's plant, catering largely for the automobile industry, good machinability was regarded as much more important than any other property, so long as the casting would do the job. When considering high proof-stress, the tendency with this grade of malleable in the States was to increase in oil-quench-and-temper treatments as compared with air-quenching-and-tempering and the customer was prepared to pay for this as it gave a higher yield- to ultimate-stress ratio.

Crack Detection and Sonic Testing

Discussing precautions to avoid oil-quench cracks, the Author replied to another question by saying that in his plant they were prepared to double quench if necessary; they were not too happy about the position of crack-detection methods and thought that some of the proprietary methods were only really useful as confirmation. Ultrasonic testing was being adopted increasingly for certain applications and proving most helpful. Founders must realize that if they were to pioneer application of a new material, the castings must be 100 per cent. sound! Still on sonic testing, a question was asked as to whether the "decay time" could be used as a "yardstick" of soundness or otherwise. Mr. Joseph said he didn't know, but thought the test was too rapid for decay time to be measured. The penultimate question asked if it was agreed that the manganese-produced pearlitic malleable made in the UK by pack-annealing would give better heat-treated properties than the American type. The lecturer agreed that it did and said some US operators were producing this grade.

Finally, when asked to put in a nutshell the advantages of pearlitic malleable crankshafts, Mr. Joseph said the application hinged on better machining (a saving of 2 to 3 dollars per shaft) as compared with forged shafts and this was the prime reason for his being able to sell the pearlitic-malleable type.

Properties of Ferritic Blackheart Malleable Cast Iron

By C. T. Moore, A.I.M.

Mr. Moore, who is associated with the British Cast Iron Research Association, described experiments carried out on the properties of ferritic blackheart malleable cast iron. In his summation, he said that the tensile properties of ferritic blackheart malleable iron might be improved by raising the silicon and phosphorus contents, or by lowering the carbon content. Increasing the silicon and phosphorus contents would raise the ultimate and proof stresses of the material and—within limits—the elongation value would not be affected. Lowering the carbon content would, however, increase all the tensile properties, including the elongation.

Side Effects

Improving the strength of the iron by increasing the silicon and phosphorus contents invariably led to a deterioration in its as-annealed ductility, as shown by the notched impact tests reported in the paper. Irons with high-phosphorus and -silicon contents had been found to be brittle in the impact test at room-temperature, but subjecting them to water quenching from 650 deg. C. and tempering at 350 deg. C. again produced the black "ductile" impact type of fractures at room-temperature. This sub-critical quenching treatment also yielded further improvement in the tensile properties and it was therefore possible, by using this heat-treatment and by raising the silicon or phosphorus content, to provide a ferritic blackheart iron which had a combination of high tensile-properties and which was fully ductile as shown by the impact test at normal temperatures.

A bend test, described in the paper, provided a simple and sensitive means of assessing the quality of the skin of malleable-iron castings. For completely ferritic materials, the bend test appeared to be little affected by the quality of the iron in the complete cross-section and it was dependent only on the skin condition. It had been shown that irons which were normally brittle at room-temperature as revealed by the impact test—provided that they had a good-quality skin—would give good bend values. Blackheart malleable cast iron, in common with other materials, could have a defective skin and the bend test was the only one which would easily reveal this condition.

Fracture Appearance

In the range of compositions studied in the paper, any change in brittle behaviour of the iron would not be indicated from the results of either the tensile test or the bend test. In these tests, however, the fracture appearance would generally exhibit some bright facets if the material was becoming brittle. On the other hand, a black fracture in the tensile or bend test did not indicate that the material would not be brittle under an impact test. Black "ductile" fractures were obtained at room-temperature in all the different types of test when the material was in the quenched and tempered condition.

In his concluding remarks, the Author said that BS.310:1958 limited the phosphorus content to 0.12 per cent. and, in practice, such high figures were rarely achieved. With the normal limitations on silicon content, and provided that the Brinell hardness was below a permitted maximum, then if the material was satisfactory in the tensile and bend tests, it should not be brittle in the notched impact test. Therefore, it was doubtful under present conditions whether the adoption of an impact test would serve any useful purpose.

Aluminium-alloy Pressure-die-castings

By J. C. Reed

In the introduction to his paper, Mr. Reed, who is sales engineer with the Birmingham Aluminium Casting (1903) Company, Limited, said that it was not always generally appreciated when referring to pressure-die-casting that the process—for certain metals—went back well over 100 years. In the 1850s, many Patents had been granted for manually-operated machines for producing castings in tin, lead, and other similar low-melting-point alloys. These were operated by forcing metal into the die by means of a piston and cylinder immersed in the liquid metal. The first commercial aluminium pressure-die-castings were made in the USA in 1915, but some 10 years had elapsed before the process was introduced into the UK. The Author described the early die-casting machines—of the air-blown or goose-neck type—the introduction of cold-chamber machines, and also described the machines in use to-day.

The largest production machine up to the present time, he said, had been developed and designed jointly by two US firms, with the object of producing larger castings, primarily for the automobile industry. The locking load of such machine was 2,000 tons. Until about a year ago, the largest machines in general use in this country were of some 500 tons locking load, and the Author regretted to state that these were either of foreign design or manufacture. The principal pressure-die-castings founders in this country had designed and built machines themselves to produce castings which had been steadily increasing in size and complexity. For example, the Author's company had laid down a 1,200 ton machine as far back as 1953. During the last two or three years, however, machine makers both in the USA and in Europe had designed and built several first-class machines of the 800-, and 1,000-ton locking-load class.

Following a description of these machines, Mr. Reed then went on to deal with the problems arising with the dispensing of metal to the machines. He said that whereas in the past the average weight of aluminium pressure-die-castings did not exceed 1 to 2 lb., with probably a maximum of 8 lb. in exceptional circumstances, the newer and larger machines were capable of producing castings weighing 40 lb. or more and, hence, some form of metal feed to the cold chamber, other than manual, must be provided. Some foundries were developing their own ideas along these lines and one automatic system was in use in the USA and to a lesser degree, in this country. Next, the Author described this system in some detail.

Vacuum Die-casting

Mr. Reed said that a great deal of attention had been given to the development of vacuum die-casting during the past five years and by many people it was looked upon as a new process. This, the Author held, was far from the truth, as the idea of applying a partial vacuum to a die cavity to remove air before the cavity was filled with metal was quite old. Revival of interest in the vacuum process in the USA had undoubtedly been caused by the demand of the American automobile manufacturer for high-quality, zinc-alloy die-castings requiring a minimum of buffing and polishing, and the Author then went on to describe this process.

Casting Alloys and Trends in Practice

Turning to the consideration of alloys which are best suited to the pressure-die-casting process, the Author said that, generally speaking, aluminium/silicon alloys, which possess a high degree of fluidity, were best suited to the process and those in most common use in the country were covered by BS. 1490, LM2M, LM6M, LM20M and LM24M. Factors affecting the choice of alloy depended very much on design and, here, it was impossible to overstress co-operation between founder and user.

In futher sections of his Paper, the Author dealt with tolerances—referring particularly to standards drawn up by the Zinc Alloy Die Casters Association and the Light Metal Founders' Association. On the subject of die development, he contrasted die weights, which, over the last few years, had increased from about ½-ton maximum to that for 800 and 1,000 ton machines which was now in the region of 4 tons. Die-making for large production jobs had posed many problems for both die-steel producers and founders, many of them overcome by a high degree of liaison.

The Author continued with a section on casting trends, in which he included a number of illustrations of typical die-cast productions of varying degrees of complexity, the notable examples quoted being a gas-cooker front-frame measuring 31 by 21 in., a pressure-die-cast combined six-cylinder crankcase and block; an assembly of very complex pressure-die-castings for an outboard engine; a gas-fire front; intricate castings for a motor-car automatic-transmission unit and the first pressure-die-cast automobile clutch-housing to be produced in quantity in the UK. Weighing 5½ lb., this last casting—in LM2M alloy—could be produced on an 800-ton machine at the rate of 50 per hr., he said.

South African Foundry Practice

By J. Steel

In this paper, the Author (secretary of the IBF South Africa branch) conveyed some general impression of the South African foundry industry and its products. The first section dealt briefly with conditions within the industry, relating to labour, methods, raw materials and equipment. Included in the first section was a description of the production of wear-resisting cast iron in a small jobbing foundry by means of oxygen lancing of the metal in a barrel-type converter. No analysis of the metal was available, the only figures being those of hardness, taken on a 4-in. circular feeder-head.

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This gave a hardness reading of 45, Rockwell C in the centre and 50 on the outer skin. The cupola was charged with a mixture of grey-and white-iron scrap plus a ferro-silicon addition; molten metal from the cupola was transferred to the converter which consisted, he said, of a steel barrel with a lining of 8-in. thick rammed magnesite formed to an internal diameter of 23 in., and a length of 24 in., with a capacity of 12 cwt. of molten metal. Oxygen at a pressure of 10 lb. per sq. in. was introduced through two ½-in. i.d., lances, their movement into and out of the barrel being controlled pneumatically. The average blowing time was 7½ min. and usually there were 12 to 15 "blows" per day at the foundry described. At the time of writing, Mr. Steele said that the current lining had given a life of over 1,100 blows under these conditions. The end of blow was determined, he added, by the flame appearance, and the barrel was then rotated manually for teeming into the casting ladle. Chromium was added to the ladle before casting.

Types of Castings

The second and main section of the paper described a variety of castings produced in South Africa, with emphasis on the types peculiar to local requirements. Mr. Steele said there was a constant demand for a wide range of iron, steel and non-ferrous castings for asbestos-, coal-, copper-, diamond- and gold-mining operations; in fact most foundries catered for one or more of the requirements of the mining industry. Headgear sheave pulleys for the mining industry were being made up to 16-ft. dia. in both steel and cast iron, and other examples of production carried out were rollers for the sugar industry, pump parts for mining, and cooking pots for the African market.

Large Example

Finally, the Author briefly described the moulding of a large bloom-shear frame-casting, measuring 11 by 11 by 9-ft. 6-in. high. For the pouring of the mould for this casting 40- and 26-ton ladles were utilized and a total of 57 tons of steel was initially poured. Subsequent melts provided metal for two after-pours, the last of which took place 7 hrs. after the initial pouring operation. The metal was melted in two electric-arc furnaces, one (of 30-tons nominal capacity) provided 42 tons, the other (of 10-tons nominal capacity) yielded 15 tons.

In his concluding remarks, the Author said that during the last war, South Africa became the workshop of the Middle East war theatre and was well placed to fulfil an important rôle in the rapid development evident to-day on the African continent. The South African foundry industry, though small and comparatively young, was an important factor in the Union's economy, and Mr. Steele hoped that his paper would provide an insight into the type of work undertaken and the conditions which applied in the industry in that sub-continent.

Moulding-sand Practice in Australia

By H. A. Stephens, B.Sc.

This paper was sponsored by the Australia (Victoria) branch of the Institute, the Author being leader of the foundry-sands section of the Chemical Research Laboratories of the Commonwealth Scientific and Industrial Research Organization. Founding in Australia, he said, began—very shortly after the first white settlers arrived in 1788—with a brass foundry, staffed by seven men and a few apprentices to cater for the needs of the infant colony. As the population grew, and new areas were settled, the founding industry developed in size and in technique until by the end of the 19th century, castings up to 20 tons in weight were not uncommon. To-day, there were some 1,000 foundries in Australia, employing a total of 22,000 men and producing 350,000 tons of castings per year. There were 15 steel foundries, 20 foundries making both steel and cast iron, 410 making grey or malleable cast iron, and nearly 600 non-ferrous foundries. Of the latter, 425 were engaged in sand casting, 60 in pressure-die-casting, and 100 in gravity-die-casting, mainly for the production of aluminium automobile castings or kitchenware. Most of Australia's large cast-iron pipes were produced in one spun-cast foundry, employing de Lavaud machines, and producing 40,000 to 50,000 tons of pipes annually. A second pipe-making plant was contemplated, Mr. Stephens said, and this would enable Australian production to be more than doubled.

Jobbing foundries in Australia, he went on, were equipped to produce castings in iron and steel up to 50 tons finished weight and in brass and bronze up to 10 tons. Although most jobbing foundries were built before 1939, the better ones were well equipped and up-to-date in their methods. Sand-slingers and pneumatic rammers were employed and large jolt machines were used where patterns could be split and bolted to a board. Loam moulding was widely employed and was the common practice for producing large pots, as well as for steel-mill rolls. In the automobile field, a six-cylinder, medium-sized car was produced, 515 per day being made. Tractors were vitally important in Australia and three firms were equipped for the production of complete tractors, while a number of others were engaged in the manufacture of auxiliary parts. One firm had just completed erection and equipping of a fully-mechanized bath foundry, capable of making 450 baths in an eight-hr. shift. Thus, the Australian foundry industry had the capacity and experience to undertake any casting required and Mr. Stephens said it compared favourably on a population basis with similar industries oversea.

Moulding Sands and Moulding Materials

Next, the Author surveyed the resources of foundry sands in the various States, dealing with New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia. Good-quality silica sands for cores and synthetic sands

he said, were readily available. In Brisbane, Perth and Hobart, these were restricted to a medium grade which was suitable for general work but not sufficiently fine for light work. The position was similar in Sydney, though some benefits were obtained from the slightly finer Gerringong sand. Adelaide dune-sands, of AFS fineness 70, provided a good surface-finish on medium and heavy casting, while in Melbourne, a finer grade was obtained, either as a reject from washing plants or by importing from the Ballarat area. In Queensland, New South Wales, and South Australia, a friable sandstone was available for the moulds of heavy castings, though that from the Sydney area was the only first-quality grade; in Victoria, coarse red sands were available for similar work. New South Wales and Victoria provided well-defined medium-grade moulding loams—those from Redhead and the Melbourne area being especially suitable. In the other States, the Author said that indifferent grades of alluvial loams associated with local streams had to be used. Good deposits of the finer grades of sand were not generally available, the exception being in the Melbourne area. The price of moulding sands varied in the different cities, but was generally low, ranging from 10s. to £2 sterling per cu. yd. (roughly 1 ton), carted for distances up to 15 to 20 miles. Thus, it was often cheaper to use new sand than to attempt costly reclamation of used sand.

Passing on to other moulding materials, the Author gave the properties of typical Australian bonding clays. Fireclays were widespread, he said, and a number of first-quality bentonites had been discovered. Recent evidence was that bentonitic clays were quite widespread in other parts of the country; a number of promising materials from both the Hunter River district of New South Wales and the western district of Victoria had been tested in the foundry sands laboratory to which he was attached.

Heavy Minerals

"Heavy" minerals were widely distributed throughout Australia, but the main mining-areas were on the beaches of northern New South Wales and southern Queensland—where zircon, rutile, and ilmenite, together with rarer minerals such as monazite, were mined.

Coal-dust used by Australian founders was ground from Maitland coal, a gas-making coal high in volatile matter with a typical proximate percentage analysis of:—Moisture 2.0, volatile matter 41.1, fixed carbon 51.4, and ash 5.5 per cent. Two main types of cereal binder were used, a pre-gelatinized starch and a core-gum based on wheaten dextrin.

Moulding-sand Practice

The Author said that moulding-sand practice throughout Australia was generally similar, with some modifications in the different States, either to suit local conditions or as a result of some special local practice. He then dealt separately with the production of heavy castings, medium-weight castings, and light castings. Touching upon core-sand practice, Mr. Stephens said that one feature peculiar to Australian practice was the extensive application of core-sand moulding, which was on a scale considerably greater than in the UK. Furthermore, the practice was more widely used in New South Wales than in any other State. The CO_2 process was relatively new to Australia, but had become widely used both for cores and moulds, and the silica sands used for oil-sand cores were also suitable as CO_2 sands.

Turning to special processes, the Author, said that two foundries—one in Melbourne and one in Sydney—were devoted exclusively to shell moulding, while a number of foundries in all States used the process as an adjunct to other methods. Cement moulding was not widespread, though a number of foundries were using the Randupson process for jobbing castings. Investment casting had not been extensively developed, but it was used to some extent for art castings and also for small components for munitions and aircraft. Two developments of this process were worth mention, however: *viz.* (1) a Melbourne sculptor had had considerable success with a modification in which a fine moulding sand rather than the normal type of material was used to invest the wax pattern; in another case, (2), wax patterns had been used to form the vanes of a pump impeller, moulded in cement sand. After the sand had set, the wax was carefully softened and pressed out by hand.

Finally, in this paper, the Author dealt with sand-preparation plant and sand control, which was much on the lines of UK practice.

Discussion

At the conclusion of his introduction to the paper, during the Malvern technical sessions on the Friday (with Mr. D. A. Richards, the new senior vice-president, in the chair), Mr. Stephens said the importance of distance should not be under-rated. For example, even within Australia, transport overland of foundry sands could cost more than bringing sand from the UK. Also, because of the isolation of foundries and their need to be self-sufficient, there was always a certain amount of make-do in the use of equipment and materials, for example, in enlarging furnace capacity on occasions and in the choice of materials for mould washes, etc., using just what was to hand. He also said that, by and large, Australian foundry practice had been built up on the accumulated "know-how" of emigrants from the UK, but thought that nowadays it did not lag much behind European practice.

Other Minerals

Asked what was the situation of olivine in Australian foundry economy, he replied that this mineral was not much used but the supplies of olivine sand were large and fairly uniform. On a point of detail, one member queried the application of a mould coat ¼-in. thick for one of the jobs referred

to in Mr. Stephens paper, saying that application of this would seem a laborious operation and one which destroyed the accuracy of the job. Mr. Stephens said this thick coating did not represent normal practice and another speaker from the audience confirmed that such a heavy application was only used for very large castings to fill a coarse-grained moulding-sand structure. Answering another question from a research-association member as to the Australian resources of refractories, etc., the lecturer replied that ilmenite was available, but had not been yet adopted in the foundry industry. On the other hand, zircon production represented a complex situation in Australia because it was a by-product of rutile separation and thus uneconomic alone. The quotation of prices therefore would not really be very helpful and in any case transport costs vitiated comparison with UK prices. As to the quality of silica sand in Australia, 99 per cent. SiO_2 sands were quite plentiful.

Contamination of Greensand by Used CO_2-process Sand

By J. M. Middleton, A.Met.,A.I.M.

This paper described some work in which a used CO_2-Process sand was added in various proportions to a new bentonite-bonded sand, and the effect of this addition upon the bonding properties and casting quality of the sand were determined. Mr. Middleton, the Author, is head of the foundry-processes section of the British Steel Castings Research Association, and at the commencement of his paper, he described two series of experiments carried out. In one, sufficient bentonite was added to all the contaminated mixes to give similar green-strength properties, and in the other, a constant 5 per cent. of bentonite addition was made to the contaminated mixes. A new sand in preference to a unit-sand base was used to determine the effects of contamination by the used CO_2-sand, as it was thought unit sands might vary much in bonding properties and behaviour according to the amount of dead clay and fines they contained.

The work carried out showed that contamination of a bentonite-bonded sand by used CO_2-sand could have a deleterious effect upon bonding properties and casting quality. The main effects of contamination were a lowering of the dry-strength of the mix and an increased susceptibility of the castings to erosion and scabbing defects. The amount of clay present in the mix had an effect upon the degree of contamination that could be tolerated before serious trouble was encountered in casting quality. With various amounts of clay additions—and working at a constant green-strength—the maximum amount used CO_2-sand that could be tolerated without affecting casting quality was 12.5 per cent., whereas when working with a constant clay addition of 5 per cent., trouble was not met until the used CO_2-sand content reached 50 per cent.

Explanations and Checks

It was probable that the increased susceptibility to scabbing defects on castings when used CO_2-sand was present was caused by a loss in bonding properties rather than by any differences in thermal-expansion properties of the sand. In fact, the expansion of the used CO_2-sand after heating to 1,200 deg. C. for two hours was less than that of a straight bentonite mix (0.9 per cent. linear expansion as against 1.5 per cent.). The degree of contamination that could be tolerated, Mr. Middleton said, would depend upon the silicate content of the used sand and the clay content of the greensand mix. Whilst it was possible—when high clay additions were made—to produce acceptable castings with rates of contamination up to 50 per cent., normally, when greensand was being controlled at a given green-strength, the amount of used CO_2-sand in the mix should not be allowed to exceed 12.5 per cent.

Finally, the Author said where used CO_2-sand was entering a unit-sand system, there were two possible methods of determining whether or not contamination was becoming serious. These were (*a*) to maintain a regular check on the green- and dry-strength properties of the mix (if it was found that the green-strength was increasing slightly whilst the dry-strength was falling, then contamination was becoming serious) and, (*b*), by making a regular check of the pH value of the sand. A combination of the two methods would, he said, possibly be more effective in assessing the degree of contamination.

Discussion

The above paper was discussed at the commencement of the Friday afternoon session, with Mr. C. H. Wilson (the immediate past-president) in the chair. The first speaker said he was disappointed in that the work was not carried far enough; a number of founders were using their sand contaminated with CO_2 binders and to do so efficiently were stepping-up the moisture content to take account of the increased activation of bentonite present by the sodium salts from the CO_2 binder. When the Author replied that steelfounders would object to using higher moisture contents in greensand and it was better for them to eliminate CO_2-sand contamination as far as possible, the first speaker said that surely to cut the bentonite addition to 3½ per cent. along with a moisture content of 3½ per cent. would be acceptable even to steelfounders. With this the Author agreed, but still held that the sand properties would not be the same as if the contamination had been avoided.

Why Use the CO_2 Process?

Another contributor, a steelfounder, asked why should members of his fraternity use the CO_2 system for moulding if they could do very well without it. Here, too, Mr. Middleton agreed that

there was no reason why they should, but many of them who did not use the Process for moulds were still using CO_2-Process cores and, from this source also, contamination could be a nuisance. He added that it should be borne in mind that the work reported on was now 2 to 2½ years old. Another contributor was of the opinion that the pH value for a sand was the real criterion of the degree of contamination.

When asked if the research had been prompted by complaints that CO_2-Process sands were causing trouble when they got into the system sand, Mr. Middleton replied in the negative; not complaints, but fears, he said. On the question whether he was still satisfied with the American type of test-casting, he replied in the affirmative—since the Association to which he belonged had standardized its moulding. It picked out poor sands but not minor differences in good sands, he added. At the conclusion of the discussion, a previous speaker reaffirmed his idea that there was little real need for steelfounders to use the CO_2 Process in any great degree and it was clear that the Author was inclined to defer to this opinion, according to circumstances.

Effect of the CO_2-Process Sands on Hot-tearing

This paper, by the same Author, described some collaborative work on the effect of CO_2-Process sands on the hot-tearing of steel, carried out by the Regional Technical Committee of the North-east Coast Association of Steel Founders and the British Steel Castings Research Association. The paper stated that a satisfactory hot-tear test-casting had been developed which, under closely-controlled foundry conditions, had proved to be sensitive to variations in the moulding material. Under such conditions, it had been found that CO_2-Process sands were no more likely to give hot-tearing than were normal dry-sands and that certain additions to CO_2-Process sands could be made which affected the propensity to tearing.

Because of the differences in practice between the various foundries carrying out the tests, wide variations in the severity of hot-tearing were obtained. The possible reasons for these variations were investigated and were discussed and it was shown that the density of the mould, the sand-milling procedure and the casting temperature employed had the greatest effect on hot-tearing.

Six Foundries

As stated previously, tests were carried out in six separate foundries, each using various types of sand mix. The types of sand mix employed were: a green sand; a dry-sand; an oil-bonded core-sand; a straight sodium-silicate/CO_2 mix, and a proprietary sodium-silicate/CO_2 mix. All the castings were produced in plain carbon steels, the carbon content being in the range 0.15 to 0.40 per cent. and the pouring temperature varying from 1,560 to 1,620 deg. C. As recorded, there was quite a considerable scatter in the results recorded by the six foundries, especially as regards the tear lengths obtained with dry- and oil-sand mixes. The general tendency was, however, for least tearing to occur with greensand mixes, followed by the silicate, and then the dry-sand mixes, the greatest tearing being associated with oil-sand mixes.

In these series of tests, the foundries concerned had used a common base-sand: namely, Chelford medium silica; a straight sodium-silicate with a $SiO_2 : Na_2O$ ratio of 2:1 at a 4.5 per cent. addition, and had standardized the making and gassing of the moulds. All the moulds were made in two parts as "boxless" moulds and gassing was effected by tubes, the total gassing time for the two halves being 5 min. All the moulds had been allowed to stand for 24 to 36 hr. before casting.

Results

Seven foundries in all had carried out the tests, each using the following CO_2-sand mixes; Chelford sand with 4.5 per cent. sodium silicate; Chelford sand with 4.5 per cent. sodium silicate and 1 per cent. bentonite; Chelford sand, 4.5 per cent. sodium silicate and 1 per cent. cereal; Chelford sand, 4.5 per cent. sodium silicate and 1 per cent. molasses, and Chelford sand with 4.5 per cent. of a proprietary silicate binder. The severity of tearing in the test casting varied appreciably from foundry to foundry but there were no definite trends in tearing without variations in the composition of the moulding materials. Results of similar tests carried out by the British Steel Casting's Research Association showed that there was a definite trend in tearing with the different mould-additives and that no improvement occurred in breakdown properties at high temperatures when organic materials, *e.g.*, molasses and cereals, were added to CO_2 sands. Least tearing was encountered with the silicate-bentonite and the straight silicate mixes, while the sand containing the proprietary binder (in which some organic materials was usually present) also gave greater lengths of tears.

Other Data

The paper also dealt with effect of casting temperature, steel composition, deoxidation practice, mould density, and milling procedure in relation to hot-tearing. A list of variables which could affect hot-tearing propensity was given as: (*a*) casting temperature—high casting temperatures aggravated tearing; (*b*) degree of ramming of the moulds—the harder and denser the moulds, the greater the degree of tearing; (*c*) intensity of milling— light milling, by maintaining high flowability of the sand mix, gave high-density moulds, producing larger tears, and (*d*) method of measuring the tears— this had an indirect effect in that the better the surface-preparation of the test casting and the more sensitive the method of assessing the tear length, the longer were the tear lengths generally reported.

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"Mould Drying"—Second Report of Sub-committee TS39 of the IBF Technical Council

The Institute's sub-committee TS 39 was inaugurated on March 14, 1951 "to review factors involved in the drying and skin-drying of moulds, with special reference to the rate of removal of moisture from the mould surface." In addition to the results of investigations into the effects of ramming density, and data on the influence of temperature on the bonding properties of sands, the report contained a summary based on the whole of the sub-committee's work over a number of years. This included theoretical and practical aspects of mould-drying and applications of the findings to the industrial field.

Effect of Ramming Density

Tests were undertaken with both natural and synthetic sands in which—for varying ramming-densities—the moisture content per unit volume of sand mass was kept constant and mould materials were dried to depths up to 3 in. Consideration of the data obtained from these tests led to the following conclusions:— (1) For a given level of water content in terms of moisture per unit volume in a sand mass, ramming density had little effect on rate of drying for depths up to 3 in. under the conditions of test. (2) For a given moisture content by weight, the quantity of water to be moved, *i.e.*, time to dry, varied with the bulk density of the aggregate. (3) The conclusion reached from previous tests on different moulding sands was confirmed, namely, that the quantity of water to be removed was the predominant factor influencing rate of drying for any given temperature of drying. (4) The relatively minor effect of permeability on the drying rate.

Heat-transfer and Moisture Movement

As stated, the moisture content present was reported to be the predominant characteristic in a sand mass to be dried, and the quantity lost or removed was dependent upon the initial content in the sand, so also was the total quantity moved. Temperature was considered to be the greatest single factor in drying, except possibly where pressurized air-flow systems were concerned. In general, therefore, the report stated that the higher the temperature of drying, the greater the dpeth dried, for a given set of conditions. Due regard, it was held, should be given to the temperature at which a particular clay-bond began to decompose when deciding the temperature to be used for drying.

Although radiant and air-circulation heating had been used in the sub-committee's investigations, no specific conclusion could be made on the effects of methods of heating on the rate of drying, since the tests had not been conducted on an industrial scale, and an evaluation under industrial conditions was considered to be outside the terms of reference of the sub-committee. It appeared that, in pressure-drying, moisture moved predominantly away from the heated face and the depth dried was proportional to the square root of time.

Reviewing the effects of the various factors as they applied to industrial mould-drying practice, the report stated that the loss in bonding properties was apparently associated with the temperatures at which a particular clay decomposed and lost chemically- combined water. The loss of this water generally began at temperatures about 400 deg. C. and, depending upon the nature of the clay, was complete at temperatures of the order of 550 to 700 deg. C., provided sufficient time was allowed at these elevated temperatures. The loss of water added to clay to condition it for moulding purposes and for the development of green bond-strength (*i.e.*, the absorbed water) took place largely at 110 deg. C., and on heating to temperatures somewhat below those at which decomposition commenced, the clay could re-absorb moisture with little effect on its natural properties. In practice, drying temperatures did not generally greatly exceed 350 deg. C., but there were exceptions for special circumstances.

Finally, the report gave foundrymen a choice of methods suitable for varying conditions of drying—and discussed the use of industrial electrodes and probes for checking, and dealt in detail with flexible probes and rigid probes.

Sand-cast Test-bar for 85/5/5/5 Gunmetal

By H. Reiter, B.Sc.(Eng.), Met.

This contribution was received from the British Non-Ferrous Metals Research Association, the Author being formerly an investigator with BNFMRA and now with J. Stone & Company (Charlton), Limited. It reported that a number of sand-cast test-bars of leaded gunmetal were tested in the laboratory in order to select a bar having consistently-high tensile-properties, with adequate sensitivity to gas content and degree of deoxidation. They included commonly-used test-bars such as the DTD, IBF, and triple BSI designs, and other cast-to-shape and parallel bars, poured through running and gating systems which permitted close control of metal flow. In the contribution, these tests were summarized and described in detail in an Appendix. Trials of the bar selected on the basis of the laboratory results were then carried out under production conditions in 14 foundries and details of these were also given.

Summary of Results

In the summary of results, the paper stated that the porosity of gunmetal test-bars increased with pouring temperature, becoming high enough to affect tensile properties when the casting temperature exceeded about 1,080 deg. C. and rising sharply for temperatures above 1,160 deg. C. The effect on tensile properties was much greater in bars having

equiaxial grain-structures than in those with a wholly-columnar structure. The scatter in properties due to variations in porosity and grain structure was smallest in a simple cast-to-shape bar, having a feeder head at each end enlarged to form a pouring cup, so that a rapid rate of pouring could be maintained. Properties obtained in industrial trials of this test-bar were as satisfactory as those obtained in the laboratory tests, although the scatter of results was somewhat greater, owing to larger variations in grain structure and composition. The porosity of the bar was moderately sensitive to gas content and deoxidation, the influence on tensile properties being such that bars containing more than 3 per cent. of the porosity had tensile strengths of about 13½ tons per sq. in. or less.

A test-bar similar to that selected from laboratory tests but cast to size and tested without machining also gave consistent tensile properties in the foundry trials, but showed little sensitivity to gas content. Whilst it was stated that the results and conclusion in this paper applied strictly to 85/5/5/5 gunmetal, the Author said that results of other laboratory tests showed that the selected cast-to-shape test-bar should be suitable for sand-cast gunmetals of other compositions. Industrial trials were now in progress to determine the scatter in properties likely to be encountered in these alloys with the selected bar.

Properties of Castings Made in Shell Moulds

By W. W. Glick, A.I.M.

This paper also emanated from the British Non-Ferrous Metals Research Association, the Author being liaison officer with that body. The object of the work described had been to obtain further information about the influence of shell-mould materials on the freezing rate and properties of three typical non-ferrous castings alloys:—(*a*) a long-freezing-range copper alloy, leaded gunmetal to specification BS. 1400, LG 2; (*b*) a short-freezing-range copper alloy, aluminium-bronze (BS. 1400, AB1) and (*c*) a long-freezing-range aluminium alloy, aluminium/copper/silicon B.S. 1490, LM4. The shells were moulded from silica/5 per cent. resin, or zircon/2 per cent. resin mixes, and a precoated silica/3 per cent. resin sand. They were used either unbacked or backed with sand, flint, or steel grit, and castings were also made in green-sand moulds for comparison. Metal test-pieces of $\frac{3}{16}$ to 1 in. section were cast, some of which were poorly fed. The amount of hydrogen pick-up, due to metal/mould reaction in leaded gunmetal containing excess phosphorus and in phosphor-bronze cast into shell moulds, was also investigated.

The Author described the experiments in detail, and sections of the paper dealt with comparison of grain-structures of leaded-gunmetal castings, the influence of mould material on cooling rate and tensile properties, the effect of grain-structure on pressure-tightness, the influences of shell thickness and backing material, and metal/mould reaction in shell moulds.

Results

It was reported that the grain structure, porosity and tensile properties of castings in aluminium-bronze and AL/Cu/Si did not vary significantly from one type to another, but those of leaded gunmetal castings varied considerably with mould materials. Results for leaded gunmetal indicated that, although the tensile properties of shell-moulded castings were likely to be at least as good as those of sand castings, the former might require more feeding for adequate pressure-tightness. The feeding required was evidently attainable in practice, for commercial shell-moulded castings were generally as pressure-tight as sand castings. A further reason for this, it was stated, might be that the high properties with a columnar grain-structure were not always realized in sand castings, because within the range of pouring temperatures which must be used in practice, inevitably some equiaxial structures were produced. A pre-coated sand appeared to have some advantage over the normal resin mixes to give pressure-tightness in gunmetal castings. In addition, greater chilling power and a moderate improvement in tensile properties could be obtained by substituting zircon for silica in shell moulds—the higher cost being largely offset if the refractory was recovered from used moulds.

Finally, the Author said that mould-reaction was much less severe with shells than with sand moulds and became excessive only when the metal was cast at temperatures above 1,150 to 1,200 deg. C. Spraying the mould with Al/Mg paint greatly reduced gas pick-up.

Discussion

Dr. A. B. Everest, B.SC., F.I.M., occupied the chair during the discussion of this paper, the first question being on the method used for the recovery of used shell-mould sand. The Author replied that simple incineration was used to reclaim sand and then, after the first speaker had put forward the view that more resin was needed to bond reclaimed sand, he agreed that this was so, but a colleague added that the economics of sand reclamation were much more apparent if zircon sand was being used. Another contributor thought it peculiar that when making aluminium-bronze castings in shell-moulds according to whether or not the shell was backed, seemed to have had little effect on the cooling rate and soundness. Was the feeding adequate on the aluminium-bronze material, he asked. The reply was that these sample castings were in fact quite sound.

Nucleation Theory Again

At this juncture, the speaker who had expressed himself doubtful of the nucleation theory in an earlier discussion again brought up the controversial point as to whether this theory really "held water." It was really inspired guessing, he

said. The Author replied the nucleation theory was the only one that fitted the case, whereupon the previous speaker said he didn't deny the presence of nuclei but thought that they only served to interpret a temperature-gradient effect. Another member of the audience was inclined to agree with this view and the Author temporized with a compromise explanation for a phenomena which all agreed was improperly understood—it was left to yet another member of the audience to describe the discordant views which had been put forward as "a red-herring anyway." At the conclusion of the commentary, the fears of a member that resin gases blowing into a shell mould as it was filled with metal would cause trouble were allayed by the Author who said he didn't think these were at all serious in their effect.

"Non-ferrous Melt-quality Tests"—Final Report of IBF Sub-committee TS45

Sub-committee TS 45 of the IBF Technical Council was set up with the following terms of reference "to investigate the possibility of developing a suitable fracture-test or other quick routine test for assessing the melt-quality of copper-base and aluminium-base alloys." In prefacing the final conclusions to the report, it was stated that the earlier work of the sub-committee was fully covered by the interim report (presented at the IBF annual conference at Buxton, May, 1958). This showed that after long research and investigations, no satisfactory test or tests meeting all the requirements of speed and positive and easily-interpreted results capable of being carried out by relatively unskilled personnel had emerged.

Discussion on this interim report had led to further work on a modified reduced-pressure solidification-test to indicate the gas content of copper-base alloys. This modified test had in fact been found to give a reliable qualitative indication of the gas content. It could be carried out in the foundry within five min., and therefore allowed corrective measures to be applied to a melt before casting. Interpretation of results by reference to previously-established standards was of course necessary, and whilst the execution of the test, it was said, required a certain amount of experience and skill, this was no greater than could be acquired by a chargehand or foreman after suitable instruction and experience. The necessary equipment could either be made up or obtained as a unit in a ready-to-use robust form, suitable for foundry use.

Further Field Trials Necessary

The reduced-pressure solidification test came nearest to meeting the terms of reference laid down for the sub-committee. The test, as regards copper-base alloys, might not be in its best or final form, but further practical work by a number of interested non-ferrous founders would, it was thought, quite quickly develop it to a higher degree of reproducibility and reliability. The sub-committee strongly recommended this test for adoption by non-ferrous foundries, where its regular use under standardized conditions would provide information of gas level from melt to melt. This it was believed would enable melting-practice to be improved, and when degassing was carried out as might be shown to be necessary, it could eliminate one variable responsible for much scrap.

The field which the sub-committee had covered had included fracture and sink tests, the reduced-pressure solidification test, fluidity test, ultrasonic inspection, density tests, and the direct measurement of hydrogen content by the Ransley "Telegas" apparatus.

Finally, the report emphasized that the sub-committee's belief had consistently been that the largest single cause of unsoundness of casting due to metal fault was high gas-content. In recommending the reduced-pressure solidification-test—which was known to work satisfactorily with aluminium alloys and aluminium-bronze, and which when modified by tin dilution could also be successfully applied to gunmetals, bronzes and phosphor-bronzes—at least one answer to the terms of reference had been achieved.

Discussion

It will be remembered that the chairman of the IBF T.S. 45 sub-committee presenting the above report was Mr. A. Logan, who died recently, and in opening the session, this fact was referred to when the chairman expressed the regret of the whole assembly at the loss of so able a foundryman. Mr. F. Hudson, F.I.M., a corresponding member of the sub-committee had been called in to present the report at Malvern and it was he who also opened the discussion with a separate contribution. The control of gas, Mr. Hudson thought, was one of the most important aspects of melt quality in gunmetal and he referred at length to recent Japanese work at Wasedo University on fracture characteristics of gunmetals. *Inter alia*, this had proved that gas pick-up in 85/5/5/5 material was much affected by phosphorus and that when no deoxidizers were present, it was very difficult to dissolve gas in the melt at all. This, Mr. Hudson said, represented quite a new conception and an alternative to using deoxidants as "finishings" was, he thought, to carry out effective degasification of melts. On this aspect, he thought that generally speaking UK founders were not too efficient in their practice. For example, why couldn't they use vacuum degassing and here he showed an illustration of a quite simple American-made equipment for this purpose.

More Field-tests Needed

Contributing to the discussion from members in the hall, the next speaker said it was a necessary step that the reduced-pressure gas-evolution test should be applied in the average foundry. Many founders in fact did not degass copper-base alloys and he held the view that it was not so very

necessary that they should, so long as the phosphorus content was kept low. In these circumstances, the tin-addition method—which was tricky to carry out—would seem to be of reduced importance. To some extent, Mr. Hudson was inclined to agree with this view but said that gas in metal was more important to makers of large castings. Another speaker agreed with him, adding that founders producing large gunmetal castings would like to have available a really good method of degassing. In this speaker's own controlled small-melt tests (about 100 of which had been carried out) he had been able only to produce gas holes in castings arising from moisture in the sand, and thus he thought metal/mould reaction would seem to be the "nigger in the woodpile."

Committee to Continue?

A member from Australia said it was unfortunate that the sub-committee appeared to be winding-up, there was still a need to correlate experiences gained in the field. This speaker went on to quote N. P. Allen's work of many years' ago to say that hydrogen was not responsible for the trouble, rather, it was the H/O_2 reaction. He thought vacuum stream-degassing of molten metal was the more efficient method to apply. Mr. Hudson, in considering these contributions, said that both types of gas trouble could have an affect on the quality of the ultimate casting and the presence of phosphorus would reduce the possibility of a "steam-reaction." Even moisture present in the air inside a mould could cause trouble, he averred. As to the perpetuation of the work, he said the sub-committee thought there ought to be an interim period during which many more field-tests should be undertaken by individual foundries.

The final contributions to the discussion included a valuable written one from a pioneer of the reduced-pressure test (with tin-addition) for gunmetals (in which the writer detailed practical hints in using the apparatus) and another speaker who asked for and was supplied with details of and desirable location in a foundry for a large vacuum-degassing unit.

Personal

Mr. L. P. SIMPSON has joined the board of Baker Perkins, Limited, engineers, Peterborough.

Mr. S. H. OLIVER has been appointed manager of the purchasing department of Castrol, Limited, in succession to the late Mr. A. J. STAFFORD.

Mr. A. E. COHEN announces that his home address is now Kilkeel, Southdean Drive, Middleton-on-Sea, Sussex.

Mr. W. C. BELL and Mr. D. L. CAMPBELL have been appointed directors of Wellman Smith Owen Engineering Corporation, Limited.

Mr. B. A. GOMM has been appointed general manager of F. Perkins (Australia) Pty., Limited, a subsidiary within the Perkins group.

Belliss & Morcom, Limited, announce that Mr. W. A. CUSINS, London manager, has been appointed export sales manager and Mr. B. NOBLE, assistant sales manager, has been appointed home sales manager.

Council of the Institution of Mechanical Engineers has awarded a James Clayton Fellowship to Mr. W. D. MORRIS for research on a compact form of heat exchanger.

Mr. GODFREY E. LIARDET, chairman and managing director of Simms Motor & Electronics Corporation, has been appointed to the board of Roadless Traction, Limited, of Hounslow, Middlesex.

Mr. P. MC. A. MARTIN, general manager of the Sprotborough Foundry, John Fowler & Company (Leeds), Limited, has been appointed local director of the company.

Mr. and Mrs. A. GARSIDE celebrated their golden wedding anniversary on July 23. Mr. Garside, aged 74, is a director of August's, Limited, engineers, King Cross, Halifax.

Mr. L. MAGEE, A.M.I.MECH.E., has been appointed works manager, Teesdale, Head Wrightson Steel Foundries, Limited. He was formerly with Crofts (Engineers), Limited, Bradford.

Mr. S. H. W. SMITH has been appointed to the board of Newman Hender & Company, Limited, in place of Major I. C. V. SMITH who has relinquished his directorship. Mr. F. V. SMITH has been appointed an additional director.

Long-service certificates and good-service gratuities were presented recently to Mr. JOSEPH C. SHARP and Mr. GEORGE CONWAY, who together have completed 106 years' service with Newton, Chambers & Company, Limited, ironfounders, engineers, and chemical manufacturers, of Thorncliffe, near Sheffield.

Mr. WALLACE MACGREGOR has been appointed president of Climax Molybdenum Company, Limited, and has been elected vice-president of American Metal Climax, the parent company, with effect from August 1. He succeeds Mr. FRANK COOLBAUGH who retired on June 1.

Sutcliffe Engineering Industries, Limited, announce the appointment of Mr. H. STREETS as a director of Sutcliffe Plant Hire, Limited, Wakefield. Mr. Streets is well known in mining-engineering circles, and is also a director of the parent company, Richard Sutcliffe, Limited, Horbury.

Mr. R. BROUGHTON has been appointed chief of the technical sales department of the Pulsometer Engineering Company, Limited, incorporating Joseph Evans & Sons (Wolverhampton), Limited, of Reading and London, designers and manufacturers of pumps and pumping equipment.

Mr. D. G. STOKES, sales and service director of Leyland Motors, Limited, has been appointed managing director of Scammell Lorries, Limited, a member of the Leyland group. He succeeds Mr. W. E. PEARSON, who retired at the end of last month. The appointment does not affect any other responsibilities now held by Mr. Stokes.

United Steel Companies, Limited, announce that Mr. E. B. REES, acting on medical advice, has resigned as export manager from July 31, but will continue to act as consultant to the company on export matters. Mr. H. A. A. WHILE, manager of the company's London office, has been appointed general export manager; he will continue to be responsible for the railways department. Mr. F. A. PLATTS will succeed Mr. While as London office manager.

British and World Shipbuilding

Lloyd's Register Returns for June Quarter

Steamships and motorships under construction in Great Britain and Northern Ireland at the end of June, according to Lloyd's Register Shipbuilding Returns for the quarter ended June 30, 1960, totalled 261 ships of 1,866,288 tons gross. This is 94,363 tons less than the previous quarter and is the lowest figure since September, 1946. The total comprises 88 ships of 599,923 tons fitting out afloat, and 173 of 1,266,365 tons still be launched.

Vessels under construction included 53 steam-ships of 990,190 tons and 208 motorships of 876,098 tons. In other Commonwealth countries there were under construction 11 steamers of 123,361 tons and 34 motorships of 106,342 tons. Oil tankers building in Great Britain and Northern Ireland totalled 55 ships of 895,175 tons, which is 95,051 tons less than the March quarter, and represents 48.0 per cent. of the total tonnage under construction in this country. Total construction in the principal districts is shown in Table 1.

TABLE 1.—*Shipbuilding Construction in Hand in Principal Districts of Great Britain and Northern Ireland.*

District.	June 30, 1960.		March 31, 1960.		June 30, 1959.	
	No.	Gross tonnage.	No.	Gross tonnage.	No.	Gross tonnage.
Aberdeen ..	19	9,236	18	8,869	17	24,361
Barrow ..	3	92,500	3	92,500	2	67,500
Belfast ..	12	217,762	15	282,840	15	293,953
Bristol ..	4	2,830	3	2,250	1	3,500
Clyde:						
Glasgow ..	51	464,720	53	490,113	46	452,914
Greenock ..	18	128,728	22	157,196	23	143,520
Dundee ..	4	22,744	4	14,158	6	40,514
Hartlepool ..	2	22,250	2	22,600	3	25,710
Hull	36	14,753	34	13,891	38	12,461
Leith	7	43,050	10	46,634	8	32,326
Liverpool ..	7	130,045	8	113,963	12	111,638
Middlesbrough	9	163,610	8	134,610	11	171,953
Newcastle-upon-Tyne	32	323,580	33	362,299	34	408,183
Southampton	11	10,979	12	11,216	7	11,064
Sunderland ..	23	214,114	21	199,018	24	215,489

The sizes of steamships and motorships under construction in Great Britain and Northern Ireland included the following:—100 to 500 tons, steam nil, motor (89); 500 to 1,000 tons, steam 2 (16); 1,000 to 2,000 tons, steam 7 (13); 2,000 to 4,000 tons, steam 3 (5); 4,000 to 6,000 tons, steam 1 (6); 6,000 to 8,000 tons, steam 2 (26); 8,000 to 10,000 tons, steam nil (17); 10,000 to 15,000 tons, steam 9 (32); 15,000 to 20,000 tons, steam 3 (2); 20,000 to 25,000 tons, steam 6 (2); 25,000 to 30,000 tons, steam 8 (nil); 30,000 to 40,000 tons, steam 7 (nil); 40,000 tons and above, steam 5 (nil).

Of the steamships and motorships under construction throughout the world at the end of June, 4,900,147 tons (53.7 per cent.) are to be classed with Lloyd's Register. Of this total 1,838,869 tons, representing 98.5 per cent. of the tonnage being built there, are at yards in Great Britain and Northern Ireland.

THOS. W. WARD, LIMITED, Sheffield, have announced that they have decided to contract out of the State pension scheme which comes into force next year, in so far as it effects their 1,500 staff employees. They have a pension scheme for staff, which provides half pay on retirement. There is no pension scheme for manual workers in the firm. Thos. W. Ward had made their decision six weeks earlier after meetings of all employees concerned.

Britain urged to join the Common Market

Fresh examination of Britain's objection to joining the European Common Market, with a view to starting negotiations towards attaining full membership of that organization, was urged in a statement issued last week by a group of leading industrialists, businessmen, and MPs. The statement argues that time is now running short, with the "Six" speeding up plans for greater unity by advancing by 12 months the fixing of a unified external tariff, as well as by making larger internal tariff cuts.

"This creates a dangerous situation for Britain, both politically and economically," says the group. "There is now little chance that the Free Trade Association of the Outer Seven can pave the way for a wider European agreement. For the Six, their own integration is the first priority and they are unlikely to reach an agreement with the Seven unless the Seven are willing to accept similar aims and principles.

"Trade war in Europe and the absence of organic links between Britain and the Six will certainly be injurious to Commonwealth interests," the group declares. "Indeed, it would seem to be in the Commonwealth's interests that Britain should share in the greater opportunities for prosperity created by a wider European economic area, and the Commonwealth should have direct links with the European market, for the system of imperial preference is insufficient for the needs of most expanding Commonwealth industries."

The statement was originally sponsored by Mr. J. Grimond, the Liberal Party leader, and among businessmen signing the statement were Sir Geoffrey Mander, chairman of Mander Bros., Limited, and Mr. A. G. B. Owen, chairman and managing director of Rubery, Owen & Company, Limited. Many MPs and members of the House of Lords are also signatories.

Midland Exports worth £2,000,000 per Day

Major C. R. Dibben, chairman of the Midland Regional Board for Industry, said at a Press conference following a meeting of the Board in Birmingham recently, that the overseas earnings of factories in the Midlands were running at around £2,000,000 a day, in spite of the fact that the export trade is largely carried by only 1,600 companies out of a potential 6,000.

The Board of Trade had submitted statistics to the Regional Board to indicate the scope for further development in the export field, and Major Dibben stressed that strong recommendations are being made to the smaller firms to make use of the services which the Government offers to encourage overseas trade.

It was reported at the meeting that unemployment in the Midland Region was down to an almost irreducible level and stands at 0.6 per cent. compared with the national average of 1.3 per cent. The total number unemployed is, at 14,084, the lowest number since 1956 while the number of vacancies stood at 44,430 almost twice that of a year ago and the highest in four years.

VOLUME of total deliveries of scientific and industrial instruments and apparatus in the first quarter of 1960 was 18 per cent. more than in the corresponding period of 1959. This was a larger increase than in any quarter of last year and deliveries for export rose by 19 per cent.

SECTION DEVOTED TO THE TECHNOLOGY OF PRODUCING DIMENSIONALLY-ACCURATE CASTINGS

Specifications for the Investment-casting Industry in the UK*

By L. S. Taylor, A.C.T.(Birm.), A.I.M., and A. G. Mason, A.C.T.(Birm.), A.I.M.

After first discussing the background to the specification problem as it affects investment founders, the Authors proceed to examine the logical development of specifications, first in relation to other steel castings and then in the particular field of investment products. Reference is also made to work in progress in the non-ferrous field and some ideas of what the future may offer.

The investment-casting industry became established in the United Kingdom during the second world war, primarily for the production of aircraft gas-turbine blades. For this reason, the first investment-cast alloys were those used and produced by the aero-engine manufacturers. Highly-alloyed steels and complex cobalt-base alloys were used, which were often in the development stage as cast alloys, and for which no recognized casting specifications existed.

Subsequent development of the process led to the production of other components which were less demanding with respect to metallurgical properties. Production commenced of components for purely commercial applications, which frequently required dimensional accuracy as being more important than controlled mechanical properties.

Early Days

In these early stages, the range of alloys cast was restricted and the use of proprietary alloys well established in the wrought field was widespread, alloys such as H. R. Crown Max being popular for many applications. During the immediate post-war period, an increasing volume of investment castings were made for parts other than aero-engine components. These could be divided into stressed high-duty castings made to supplier's or consumer's specifications, and commercial castings produced against composition with little or no mechanical testing.

Most of the castings replaced components which would normally have been machined from wrought bar or forgings, and it was usual for designers to call for wrought specifications and properties when designing castings. The most common specifications called for were the B.S.S. (Aircraft) and the BS. 970 En series. Difficulties and loss of confidence resulted when it was realized that the properties called for could not always be fulfilled by castings. This led to a feeling that castings had lower strength than wrought products. It was not realized that the majority of wrought materials will only meet the specification requirements on test-pieces produced with the grain flow in the most favourable direction. Uniformity of properties is one of the main advantages of castings and was clearly illustrated by F. W. Rowe† whose data are reproduced in Tables 1 and 2.

In the commercial field, a whole series of low-alloy and stainless steels were cast, based on the compositions of the BS. 970 En series for wrought steels. The result was that a very large number of so-called "specifications" existed, of which the majority were unsatisfactory and based on limited experience. No British Standard existed for investment castings and the conventional steel casting standards then available were unsuitable for the alloys being cast.

Development of Investment-casting Specifications

In the late 1940's, two Ministry of Supply Specifications D.T.D. 666 and 705 were issued, covering medium-high-tensile and high-tensile steel sand castings. These called for the highest quality steel casting with respect to tensile and impact properties with all castings subject to radiological examination and magnetic crack-detection. The success of certain foundries in meeting these specifications showed that if close metallurgical-control was applied at all stages, then the highest quality components could be made as investment castings. This acceptance of investment castings for air-frame parts led to the issue in 1957 of D.T.D. 5072—the first investment-castings specification to be issued in the United Kingdom by any body other than the casting producers or users.

These Ministry specifications to which all Class 1 air-frame castings should be made, provide only for medium and low-alloy steel compositions. They

* Paper presented at the second annual conference of the British Investment Casters' Technical Association. The Authors are attached to G. L. Willan, Limited.

† F. W. Rowe: "Steel Castings and their Application." Customer Founder Convention of the British Steel Founders Association, 1953.

TABLE 1.—*Comparison of Mechanical Properties of Equivalent Wrought and Cast Steels.*

Type of steel and condition.	—	Yield strength. tons per sq. in.	Tensile strength. tons per sq. in.	Elong. per cent. on 2-in. g.l.	Red. of area.	Izod value, ft.-lb.
Plain carbon steels: 0.20 per cent. carbon steel (normalised)	Wrought steel.—In direction of rolling	18.0	32.4	29.0	46.0	40
	Wrought steel.—At 90 deg. to direction of rolling	17.6	31.2	15.0	12.0	11
	Cast steel	17.8	31.6	30.0	44.7	35
0.40/0.45 per cent. carbon steel (normalised)	Wrought steel.—In direction of rolling	21.2	39.2	29.0	36.5	21
	Wrought steel.—At 90 deg. to direction of rolling	20.8	37.2	10.0	10.3	10
	Cast steel	23.2	40.0	24.0	33.0	18
(quenched and tempered to 40 tons per sq. in.)	Wrought steel.—In direction of rolling	—	47.6	23.0	44.7	41
	Wrought steel.—At 90 deg. to direction of rolling	—	48.4	17.0	23.2	12
	Cast steel	—	48.6	22.0	40.0	35
Low-alloy steels: Mn/Mo steel (quenched and tempered to 45/55 tons per sq. in.)	Wrought steel.—In direction of rolling	—	48.0	24.0	52.3	79
	Wrought steel.—At 90 deg. to direction of rolling	—	48.0	16.0	29.3	9
	Cast steel	35.5	49.6	23.0	43.4	56
(quenched and tempered to 55/65 tons per sq. in.)	Wrought steel.—In direction of rolling	—	59.6	21.0	50.9	57
	Wrought steel.—At 90 deg. to direction of rolling	—	57.6	10.0	23.5	12
	Cast steel	54.0	61.6	17.0	32.0	44
1¼ per cent. Ni/Cr/Mo steel (quenched and tempered to 55/65 tons per sq. in.)	Wrought steel.—In direction of rolling	—	60.8	19.0	49.8	72
	Wrought steel.—At 90 deg. to direction of rolling	—	56.0	5.0	6.9	29
	Cast steel	53.7	60.4	16.0	35.0	45

Explanatory notes on preparation of test-pieces: (1) Wrought steels—All tests were cut from 6-in. dia. bar, except for 0.40/0.45 per cent. carbon steel in the heat-treated condition, and the Mn/Mo steel in the 55/65 tons per sq. in. condition. These were treated in the sections specified in B.S. 970 for the stated condition, namely, 2-in. section and 2½-in. section respectively, although cut from 6-in. dia. stock. (2) Cast steels—all tests were cut from "clover-leaf" bars.

TABLE 2.—*Chemical Composition of Steels referred to in Table* 1.

Type of steel.		Composition, per cent.							
		C	Mn	Si	S	P	Ni	Cr	Mo
0.20 per cent carbon:									
Wrought	EN3A	0.22	0.81	0.20	0.010	0.040	0.16	tr	tr
Cast	KL201	0.21	0.80	0.40	0.014	0.031	—	—	—
0.40/0.45 per cent carbon:									
Wrought	EN8	0.41	0.74	0.28	0.033	0.035	0.16	tr	tr
Cast	KL501	0.42	0.69	0.40	0.019	0.023	—	—	—
Low-alloy—Mn/Mo steel:									
Wrought	EN16	0.38	1.53	0.12	0.017	0.030	0.10	tr	0.16
Cast	KL111	0.34	1.35	0.40	0.027	0.033	0.70	0.55	0.31
1¼ per cent Ni/Cr/Mo:									
Wrought	EN24	0.39	0.84	0.28	0.010	0.025	1.38	1.04	0.28
Cast	—	0.38	0.62	0.39	0.020	0.028	1.57	0.74	0.35

do not cover the corrosion-resistant and stainless steels. Work on the difficult 13 per cent. chromium type is the subject of a joint research project to be carried out by the British Steel Castings Research Association and the British Investment Casters' Technical Association; and a draft specification for the austenitic stainless steels is being prepared by the Ministry of Aviation.

In 1957, the British Standards Institution issued BS. 3100 which presented all the existing British Standards for steel castings in one series. These were the only nationally recognized steel-casting specifications available to the investment founder and, as experience has been gained, increasing use has been made of them up to the present time (Table 3).

As the BS. 3100 series of specifications was drawn up for the conventional steel foundry, there were difficulties for the investment founder in working to them. Principal amongst these was the difference in the size of the normal steelmaking cast and that of the investment foundry. The effect of this was to call for a disproportionate amount of analytical and mechanical testing from the small investment foundry cast which was usually of the order of 15 to 30 lb. Another difficulty was the omission of well-established investment-cast alloys, such as the low-carbon case-hardening steels.

In response to the growing demand from the industry, the British Standards Institution formed a committee entrusted with the preparation of investment-casting standards. This committee was widely drawn from representatives of the engineering industry, the Ministry of Supply and investment foundries. As a result of their work, BS. 3146 "Investment Castings in Metal, Part 1, Carbon and Low Alloy Steels," was issued in September, 1959. This covers steels from the low-carbon type up to the 75 ton tensile alloy steel. A summary of these specifications is given in Table 4.

The aims of this series of specifications were (*a*) to include those alloys which had not previously been covered; (*b*) to establish a more realistic basis for the mechanical and analytical testing; (*c*) to omit those alloys which were unsuitable for investment casting; and (*d*) to bring all the investment-casting alloys into one series of specifications.

One early difficulty in drawing up investment-casting specifications was the lack of a central body or association through which foundries could exchange information and reach general agreement. The formation of BICTA enabled this to be done through the appointment of its Metal Specification Committee. This committee has collected views and mechanical testing data, and through its representation on the British Standards Institution committee has been able to assist in drawing up a realistic British Standard which is acceptable to customers, inspecting authorities, and the majority of investment founders.

Discussion of New Standards

One seriously contested point was the basis on which both mechanical and analytical testing should be carried out, and the exact requirements of BS. 3146 in this respect are worthy of mention. Analytical control is governed by Clause 3 of Section 1 which states:—" and if so stated on the enquiry and order, the manufacturer shall supply a certificate of the chemical analysis on a basis agreed between the manufacturer and the purchaser ". The frequency of mechanical testing is covered in Clause 9 of Section 1, which states: " one full set of tests per heat-treatment batch shall be applied ". The above clauses would appear to adequately meet the special requirements of the small investment-foundry melt.

It is important when drawing up standards that they have at least national and preferably international authority. Establishing the confidence of customers and inspecting authorities in new specifications is of prime importance and for this reason it was considered that it would be unwise to draw up specifications for investment castings under the auspices of an investment-casting association when the danger would have existed of the standards being influenced in favour of the founders at the expense of customer requirements. For this reason, it was considered that the body responsible for issuing standards for the United Kingdom should be the British Standards Institution. It is important, however, that the views and needs for revision as seen by the founder should be co-ordinated and discussed, so that representations can be made to the British Standards Institution with the maximum authority.

To a very great extent, the mechanical properties called for by the corresponding British Standards for steel castings, have been adopted for investment castings. This would appear to be reasonable and seemed justified in the data that was available to the BSI committee when drafting BS. 3146, but to confirm this and to provide an authoritative record, a statistical survey of the mechanical-test results from a number of companies for several types of material has been carried out by the BICTA metal specification committee, and some of the results are given below.

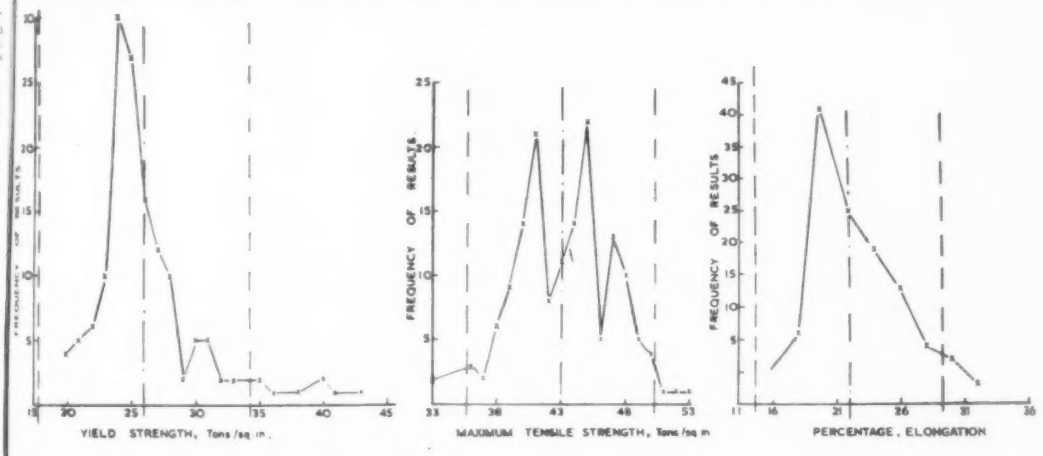

FIG. 1.—*Test data on the mechanical properties of steel to CLA. IC. (BS 592 C). Yield stress:—mean value* 26.0 *tons per sq. in. and standard deviation* 4.1 *tons; ultimate tensile strength:—mean value* 43.0 *tons per sq. in., and standard deviation* 3.7 *tons, and elongation:—mean value* 22 *per cent. and standard deviation* 3.6 *per cent.*

Mechanical-test Data

The initial data covered those steels to be included in Part 1 of BS. 3146. This was to confirm that the mechanical properties called for in BS. 3100 could be adopted for the new standards covering investment castings. Statistical evidence based on several hundreds of results was considered desirable.

Representative distribution curves are shown in Figs. 1 to 6 which illustrate the use of the data submitted. Each curve is marked with three vertical lines. The centre (chain-dotted) line shows

TABLE 3.—*BS. 3100: 1957 Summary of Compositions and Mechanical Properties of Steels.*

Specn.	Grade.	Type of steel.	Chemical composition, per cent. (maxima unless otherwise stated).											Tensile strength min.		EL. per cent. min.	Izod ft.-lb.
			C	Si	Mn	Ni	Cr	Mo	Cu	Nb	Ti	S	P	Tons per sq. in.	Kg. per sq.mm		
Bs. 592	A	Plain carbon..	0.25	0.60	1.00	0.40	0.25	0.15	0.30	—	—	0.060	0.060	28	44	22	—
	B	Plain carbon..	0.35	0.60	1.00	—	—	—	—	—	—	0.060	0.060	32	50	20	—
	C	Plain carbon..	0.45	0.60	1.00	—	—	—	—	—	—	0.060	0.060	35	55	15	—
BS. 1398		Carbon/Mo ..	0.15/ 0.25	0.20/ 0.50	0.50/ 1.00	0.40	0.25	0.40/ 0.70	0.40	—	—	0.050	0.050	30	47	20	15
BS. 1456	A	1½ per cent. Mn	0.18/ 0.25	0.50	1.20/ 1.70	—	—	—	—	—	—	0.050	0.050	35/ 45	55/ 71	18	25
	B		0.25/ 0.33	0.50	1.20/ 1.70	—	—	—	—	—	—	0.050	0.050	45/ 55	71/ 87	15	20
BS. 1457		Austenitic Mn	1.0/ 1.35	1.0	11.0 min.	—	—	—	—	—	—	0.060	0.10	—	—	—	—
BS. 1458		45/55 ton alloy	—	—	—	—	—	—	—	—	—	0.050	0.050	45/ 55	71/ 87	15	25
BS. 1459		55/65 ton alloy	—	—	—	—	—	—	—	—	—	0.050	0.050	55/ 65	87/ 102	12	15
BS. 1461		3 per cent. Cr/Mo	0.25	0.75	0.30/ 0.60	0.40	2.50/ 3.50	0.35/ 0.60	0.40	—	—	0.050	0.050	40/ 50	63/ 79	18	20
BS. 1462		5 per cent. Cr/Mo	0.20	0.75	0.40/ 0.70	0.40	4.00/ 6.0	0.45/ 0.65	0.40	—	—	0.040	0.040	40	63	18	—
BS. 1463		9 per cent. Cr/Mo	0.20	1.00	0.30/ 0.70	0.40	8.00/ 10.0	0.90/ 1.20	0.40	—	—	0.040	0.040	40	63	18	—
BS. 1617	A	High-magnetic-permeability (mild)	0.15	0.60	0.50	0.40	0.25	0.15	0.40	—	—	0.060	0.060	28 × 26/ 32	44 × 41/ 50	22	—
	B		0.25	0.60	0.50	0.40	0.25	0.15	0.40	—	—	0.060	0.060			20	
BS. 1630	A	13 per cent. Cr	0.15	1.00	1.00	1.00	11.5/ 13.5	0.15	0.40	—	—	0.050	0.050	35	55	20	—
	B		0.12/ 0.20	1.25	1.00	1.00	11.5/ 13.5	0.15	0.40	—	—	0.050	0.050	40	63	18	—
	C		0.20/ 0.30	1.00	1.00	1.00	11.5/ 13.5	0.15	0.40	—	—	0.050	0.050	45	71	15	—
BS. 1631	A	Austenitic	0.12	2.00	2.00	7.00 min.	17.0 min.	—	—	—	—	0.045	0.045	30	47	20	—
	B	Nb/Cr/Ni	0.12	2.00	2.00	8.5 min.	17.0/ 20.0	—	—	8 × C/ 1.10	—	0.045	0.045	30	47	20	—
	B	Ti	0.12	2.00	2.00	7.5 min.	17.0/ 20.0	—	—	—	4 × C/ 0.70	0.045	0.045	30	47	20	—
BS. 1632	A	Austenitic ..	0.08	1.50	2.00	11.0/ 14.0	18.0/ 20.0	3.00/ 4.00	—	—	—	0.050	0.050	30	47	15	—
	B	Cr/Ni ..	0.08	1.50	2.00	10.0 min.	16.5/ 18.5	2.00/ 3.00	—	—	—	0.045	0.045	30	47	15	—
	C	Nb	0.12	1.50	2.00	10.0 min.	16.5/ 18.5	2.25/ 2.75	—	8 × C/ 1.10	—	0.045	0.045	30	47	15	—
	C	Ti	0.12	1.50	2.00	10.0 min.	16.5/ 18.5	2.25/ 2.75	—	—	4 × C/ 0.70	0.045	0.045	30	47	15	—
	D		0.08	1.50	2.00	8.00 min.	16.5/ 18.5	2.00/ 3.00	—	—	—	0.045	0.045	30	47	15	—
BS. 1648	A	Heat-resisting alloy	0.25	2.0	1.0	—	12.0/ 16.0	—	—	—	—	—	—	—	—	—	—
	B		1.0	2.0	1.0	—	25.0/ 30.0	—	—	—	—	—	—	—	—	—	—
	C		1.0/ 2.0	2.0	1.0	—	25.0/ 30.0	—	—	—	—	—	—	—	—	—	—
	D		0.4	2.0	2.0	6.0 min.	17.0/ 22.0	—	—	—	—	—	—	—	—	—	—
	E		0.5	2.5	2.0	10.0/ 14.0	22.0/ 27.0	—	—	—	—	—	—	—	—	—	—
	F		0.5	3.0	2.0	17.0/ 22.0	22.0/ 27.0	—	—	—	—	—	—	—	—	—	—
	G		0.5	3.0	2.0	23.0/ 28.0	15.0/ 20.0	—	—	—	—	—	—	—	—	—	—
	H	Heat-resisting alloy	0.5	3.0	2.0	36.0/ 46.0	15.0/ 25.0	—	—	—	—	—	—	—	—	—	—
	K		0.75	3.0	2.0	55.0/ 65.0	10.0/ 20.0	—	—	—	—	—	—	—	—	—	—
BS. 1760	A	Plain carbon (surface hardening)	0.45/ 0.50	0.60	1.00	0.40	0.25	0.15	0.40	—	—	0.060	0.060	40	63	12	—
	B		0.55/ 0.65	0.60	1.00	0.40	0.25	0.15	0.40	—	—	0.060	0.060	45	71	10	—
BS. 1956	A	1 per cent. Cr	0.45/ 0.55	0.75	0.50/ 1.00	—	0.80/ 1.20	—	—	—	—	0.060	0.060	45	71	10	—
	B		0.45/ 0.55	0.75	0.50/ 1.00	—	0.80/ 1.20	—	—	—	—	0.060	0.060	—	—	—	—
	C		0.55/ 0.65	0.75	0.50/ 1.00	—	0.80/ 1.50	0.20/ 0.40	—	—	—	0.060	0.060	—	—	—	—

the mean value of the values plotted, while the outer lines are each spaced at a distance equivalent to two standard deviations from the mean. It is known that for a regular distribution curve, the range covered by the mean, plus and minus two standard deviations includes 94 per cent. of the values considered. Thus, since the remaining 6 per cent. are equally divided above and below the limits of this range, 3 per cent. will fall below the minimum value. Most foundries are unwilling to accept a specification which incurs much more than 3 per cent. of scrap, due to the minimum value of mechanical properties being too high, and it was considered that the range of mean plus and minus two standard deviations was a sensible criterion to use.

The data for type CLA 1C steel were those obtained from test-pieces made to satisfy BS. 592C. Fig. 1 shows that the limits representing the mean minus two standard deviations are in agreement with the minimum values required by BS. 592C. These properties were accepted as being realistic for the new CLA 1C specification.

Results for the CLA 7 specification, were those obtained from working to BS. 1461 and various proprietary specifications covering the same type of material heat-treated to the 40 to 50 ton per sq. in. tensile range. The distribution curves are shown in Fig. 2. The minimum values for UTS and elongation and the maximum UTS. are in reasonable agreement with BS. 1461. The curve for Izod properties shows a minimum value (mean range

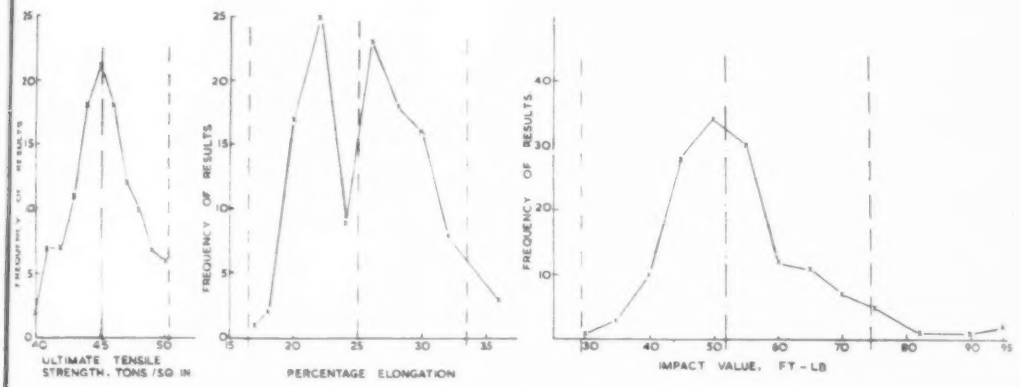

FIG. 2.—*Test data on the mechanical properties of steel to C.L.A.7. Ultimate tensile stress:—mean value* 45.2 *tons per sq. in., standard deviation* 2.6 *tons per sq. in. Elongation:—mean value* 25 *per cent. and standard deviation* 4.25 *per cent. Izod impact:—mean value* 52 *ft.-lb. and standard deviation* 11.2 *ft.-lb.*

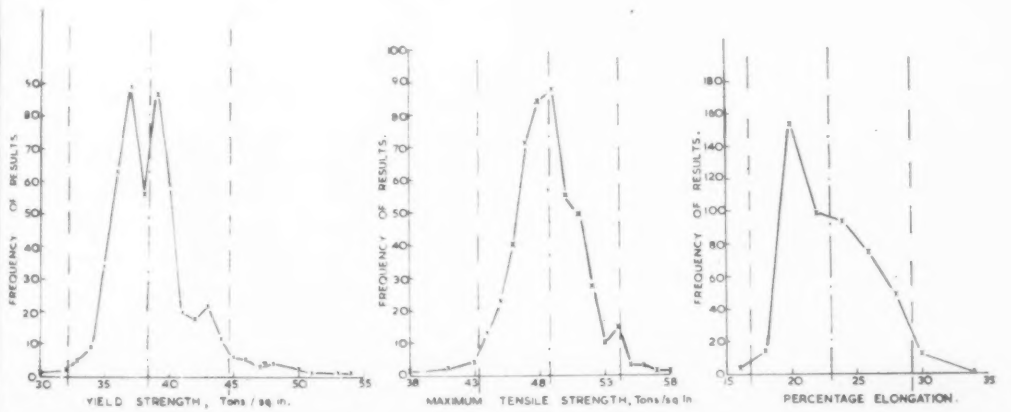

FIG. 3.—*Test data on mechanical properties of steel to BS.* 1630 *B* (500 *results). Yield stress:—mean value* 38.4 *tons per sq. in. and standard deviation* 3.1 *tons. Ultimate tensile stress:—mean value* 48.8 *tons per sq. in. and standard deviation* 2.7 *tons. Elongation :—mean value* 23.0 *per cent., standard deviation* 3.1 *per cent.*

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minus two standard deviations) as approximately 30 ft.-lb. This is appreciably in excess of the 20 ft.-lb. minimum value required by BS. 3146, and, after some discussion, the value of 25 ft.-lb. was agreed—an increase of 5 ft.-lb. over the requirement of BS. 1461.

Figs. 3 and 4 show distribution curves for BS. 1630B and BS. 1631B. Little significant difference is apparent between these specifications and those now under consideration for Part 2 of BS. 3146. The distribution curve shown in Fig. 5 amply illustrates the variability of impact properties known to be characteristic of 13 per cent. chromium steel heat-treated to strengths over 50 tons per sq. in. The mean value for Izod impact strength is 20 ft.-lb., and the standard deviation value of 9 ft.-lb. means that the range covering 94 per cent. of the results is 2 to 38 ft.-lb. This gives us a useful standard against which to compare the results obtained from the research programme now to be carried out on the impact properties of 13 per cent. chromium steel.

In the case of the copper-base alloys, the data so far available is limited, and only in the case of BS. 1400 PB 1C were sufficient results available for statistical analysis. Seventy-four results were available, and the distribution curves obtained are shown in Fig. 6.

The three main peaks which occur on the elongation curve are not easily explained, though this test is more subject to operator error than any of the others. The mean value obtained is 42 per cent. with a minimum value of just over 15 per cent. The BS. 1400 PB 1C minimum value of 1.5 per cent. is clearly unrealistic with respect to investment castings. Similarly, the specification requirement of 12 tons per sq. in. ultimate tensile stress could be increased by a half to 18, and an even greater increase may be justified when more data are available.

One outstanding feature of the data submitted by BICTA members is the wide divergence of heat-treatments used to achieve similar properties. By analysing the data, the BICTA metal specifications committee hope to be able to recommend to members the most satisfactory treatments.

The data collected from BICTA members have been used to assess the suitability of property values suggested for specifications for investment castings and will be used in a similar manner for future specifications. Statistical analysis is particularly useful when draft specifications are being prepared when no previous casting specifications are available for guidance. It can be used to assess heat-treatments, variations of composition and such variables as alternative melting and casting techniques, such as those proposed for 13 per cent. chromium steels. It should be stressed here,

TABLE 4.—*BS 3146: 1959, Part 1—Summary of Compositions and Mechanical Properties.*

Specification.	Grade.	Type of steel.	Chemical composition, per cent (maxima unless otherwise stated).									Tensile strength, min.		Elongation, per cent, min.	Izod, ft.-lb.
			C	Si	Mn	Ni	Cr	Mo	Cu	S	P	Tons per sq. in.	Kg. per sq. mm.		
CLA 1	A	Plain carbon ..	0.25	0.60	1.00	0.40	0.25	0.15	0.30	0.050	0.050	28	44	22	—
	B		0.35	0.60	1.00	0.40	0.25	0.15	0.30	0.050	0.050	32	50	20	—
	C		0.45	0.60	1.00	0.40	0.25	0.15	0.30	0.050	0.050	35	55	15	—
CLA 2	A	1½ per cent. Mn ..	0.18/0.25	0.50	1.20/1.70	0.40	0.25	0.15	0.30	0.050	0.050	35/45	55/71	18	25
	B		0.25/0.33	0.50	1.20/1.70	0.40	0.25	0.15	0.30	0.050	0.050	45/55	71/87	15	20
CLA 3	—	45/55-ton alloy ..	—	—	—	—	—	—	—	0.050	0.050	45/55	71/87	15	25
CLA 4	—	55/65-ton alloy ..	—	—	—	—	—	—	—	0.050	0.050	55/65	87/102	12	15
CLA 5	A	High-tensile ..	—	—	—	—	—	—	—	0.020	0.025	60	94	12	30
	B		—	—	—	—	—	—	—	0.020	0.025	75	118	7	10
CLA 6	—	Carbon Mo ..	0.15/0.25	0.20/0.50	0.50/1.00	0.40	0.25	0.40/0.70	0.40	0.050	0.050	30	47	20	15
CLA 7	—	3 per cent. Cr Mo	0.25	0.75	0.30/0.60	0.40	2.50/3.50	0.35/0.60	0.40	0.050	0.050	40/50	63/79	18	25
CLA 8	—	Surface-hardening, carbon	0.35/0.45	0.60	0.50/0.80	0.40	0.25	0.15	0.40	0.050	0.050	35	55	15	—
CLA 9	—	Carbon, case-hardening	0.10/0.18	0.25/0.60	0.60/1.00	0.40	0.30	0.15	0.30	0.050	0.050	32	50	20	20
CLA 10	—	3 per cent.-Ni case-hardening	0.10/0.18	0.25/0.60	0.30/0.60	2.75/3.50	0.30	0.15	0.30	0.050	0.050	45	71	18	30
CLA 11	—	3 per cent.-Cr Mo	0.20/0.30	0.25/0.75	0.30/0.60	0.40	2.90/3.50	0.40/0.70	0.40	0.045	0.045	55/65	87/102	12	15
CLA 12	A and B	1 per cent.-Cr ..	0.45/0.55	0.75	0.50/1.00	0.40	0.80/1.20	0.15	0.40	0.050	0.050	45	71	10	—
	C		0.55/0.65	0.75	0.50/1.00	0.40	0.80/1.50	0.20/0.40	0.40	0.050	0.050	—	—	—	—

that the quality of data submitted must be large, if the results achieved are to be of any real value.

Work in Progress

The BSI Committee responsible for standards for investment castings is now engaged in drawing up Part 2 of BS. 3146. Since this Part 2 has not been issued to industry for comment, it is not permissible to discuss subjects which are put forward. However, it is not considered to be indiscreet to say that Part 2 is expected to cover 13 per cent. chromium, 18/8 austenitic steels, and ferrous, nickel- and cobalt-base creep- and corrosion-resistant alloys. It is hoped that a draft standard will be issued for comment to industry during 1960 and that the final specification will be issued during 1961.

Institution for including these within the BS. 3146 Standard for investment castings.

Future Work

One of the disadvantages in the provision of test bars in investment moulds is the size of the test bar and its feeding system to comply with standard sizes. A particular example of this is the three-notch Izod impact test-piece. This is an expensive item when the number of saleable castings displaced is considered. There is a need for a smaller impact test-piece, acceptable to the British Standards Institution, and this project deserves attention by BICTA and investment founders generally.

By the very nature of the process, the investment-casting industry is closely associated with develop-

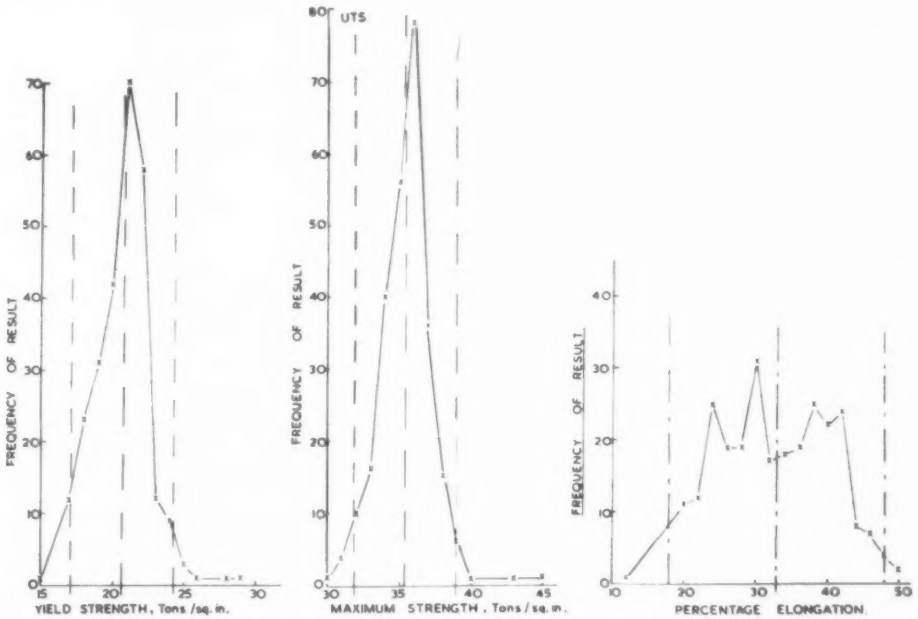

FIG. 4.—*Test data on the mechanical properties of steel to BS.* 1631 *B* (264 *results*). *Yield stress:—mean value* 20.6 *tons per sq. in., standard deviation* 1.8 *tons. Ultimate tensile stress:—mean value* 35.4 *tons per sq. in., standard deviation* 1.8 *tons. Elongation :—mean value* 33.0 *per cent. standard deviation* 7.5 *per cent.*

A growing demand has arisen for standards for investment-cast copper and aluminium-base alloys, and BICTA is collecting mechanical-test data and comments concerning these alloys. Some of these results are shown in Fig. 6. There is overwhelming evidence that the properties obtained from investment castings greatly exceed the properties called for by some of the existing British Standards specifications for conventionally-cast copper-base alloys and when all the data has been received and further comments obtained from members, it is likely that representations will be made to British Standards

ments in high-temperature engineering, not only for aircraft gas turbines but for an increasing industrial market. For high-temperature materials, the methods for assessing quality will be different from those used for room-temperature applications. Demands for chemical analysis will be far more exacting and the reliable assessment of high-temperature properties can only be determined by some acceptable form of creep testing. This raises a problem as to whether the investment foundries would be able or prepared to carry out these exacting analyses and high-temperature creep-tests.

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It may be that the supplier of the parent stock, who is usually in a better position to do this work, should fulfil these conditions for the bar provided for remelting. The absence of creep-testing requirements in high-temperature specifications could well be an obstacle to designers in the wider application of creep-resisting investment castings, and it justifies consideration by the founders.

The influence of technical advances on properties and specifications has recently been illustrated by improved melting and casting techniques for the 13 per cent. chromium corrosion-resisting steels. This alloy has been well known over a wide number of years, not only in the investment casting industry but in the conventional steel-castings industry, for

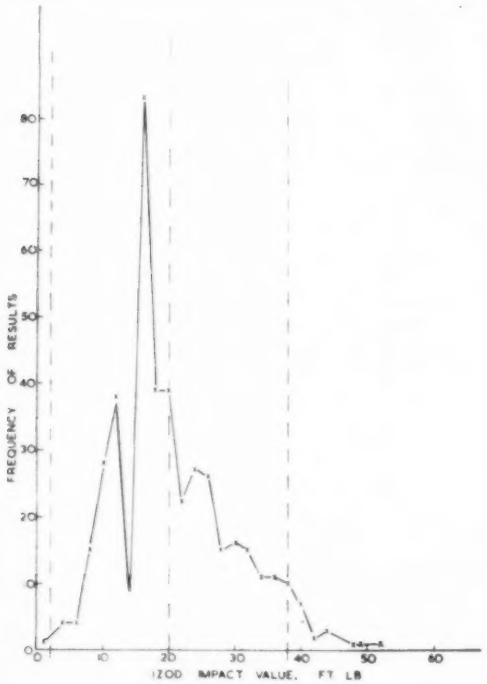

FIG. 5.—*Impact values on* 13 *per cent. Cr steel to* 50/60 *tons per sq. in. tensile strength* (418 *results*). *Izod impact:—mean value* 20 *ft.-lb. and standard deviation* 9 *ft.-lb.* (*Data from one company only*, i.e., *Deritend Precision Castings, Limited.*)

its variable impact-strength, particularly when exceeding tensile strengths of 50 tons per sq. in. It was because of this variable impact-property that a proposal to issue a DTD specification for this class of material was withdrawn. This represents a loss of potential trade to the investment-casting industry. With this in mind, the question of variable impact-values of this material has been discussed by the BICTA metal specification committee. Recent work by one of its members, D. Napier & Sons, Limited, to whom the Authors are indebted for this information, has shown that modified melting techniques available to the investment caster show convincing evidence of having overcome this problem; for impact values lying in the range of 95 to 108 ft.-lb. have been obtained as compared with values of 8 to 30 ft.-lb. by conventional methods. It is hoped that the research programme to be carried out by the British Steel Castings Research Association with the support of BICTA will, in the not too distant future, provide sufficient information to enable both the

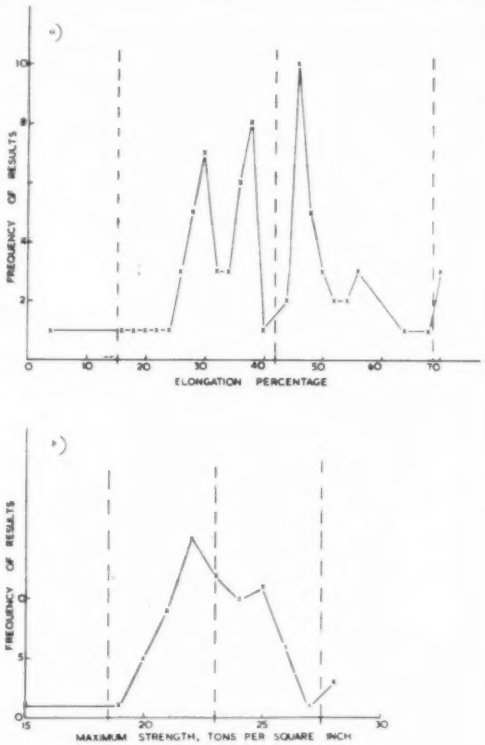

FIG. 6.—*Test data on the mechanical properties of phosphor-bronze to BS.*1400 *PBIC* (74 *results*). (a) *Elongation:—mean value* 42 *per cent. and standard deviation* 13.4 *per cent., and* (b) *ultimate tensile stress:—mean value* 23 *tons per sq. in. and standard deviation* 2.27 *tons per sq. in.*

Ministry of Aviation and the British Standards Institution to issue specifications incorporating impact values acceptable to both users and investment casters.

One danger to be guarded against is that of new alloys being put forward for standardization on a too limited basis of experience of the castability

and metallurgical problems in producing sound castings. Particularly is this so when materials appear to offer properties which appeal to designers. Examples of this occur in the so-called "super alloys," several of which can give most attractive test-bar properties, but offer serious foundry difficulties in producing sound castings. It is only by collecting information from industry and discussing it between founders that the merits and difficulties associated with particular alloys can be assessed and only suitable alloys put forward for standardization.

The Authors have tried in this paper briefly to trace the history of specifications for investment castings, the present position, the information that is available to them and work that is being carried out, together with some thoughts on possible trends in the future. Some of the views expressed for the future are intentionally provocative since it is felt that it is only by discussion and exchange of views that sensible steps can be taken for the preparation of future standards. The Authors thank members of BICTA for the mechanical-test data they have submitted and for their valued comments.

APPENDIX

Standard Deviation

If some variable quantity such as heights of men or their intelligence quotients is measured, the results of the measurements may be plotted, with the individual values on the horizontal axis, and the frequencies with which these values occur on the vertical axis. In the case of intelligence quotients, a few genii and a few idiots will be discovered, while the majority fall between these two extremes. The larger the number of measurements made, the more nearly will the curve produced approach the ideal form of the normal distribution, providing that no external variable influence is exerted on the variable being considered. This ideal normal distribution is symmetrical about its mean, which coincides with its peak value. The standard deviation is a measure of the deviations of the individual measurements from the mean. It is calculated by the formula:—

$$s = \sqrt{\frac{(x - \bar{x})^2}{n}}$$

where s = standard deviation, x = individual values, $\bar{x}$ = mean value, and n = number of measurements.

The relationship between the normal distribution and the standard deviation is that the range covered by the mean value plus and minus one standard deviation contains 68 per cent. of the individual values considered, the range mean plus and minus two standard deviations contains 94 per cent., and the range mean plus and minus three standard deviations contains 99.7 per cent.

REFERENCES

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[2] Brownlee, *Industrial Experimentation*, HMSO.
[3] Martin, A. R., "Rôle of Statistical Methods in Controlling the Quality of Non-ferrous Castings," *J. Inst. Met.*, **85**, 1956-57.

Metallurgical Abstract

Steel Castings for High-duty Applications. H. E. HUBSCHER. (*Metal Progress:* 1960; vol. 77; No. 1; pp. 77-81). Steel castings which have uniform properties in all directions are now being made in Switzerland. By virtue of alloying and heat-treatment, these properties can include tensile strengths as high as 85 tons per sq. in., and excellent resistance to cavitation and to corrosion by various chemicals. The melting shop at George Fischer, Limited, has four basic-lined electric-arc furnaces, ranging from 8 to 30 tons capacity. All have a swinging roof for top charging and the 30-ton furnace is equipped with a magnetic-stirring device. Induction furnaces with capacities from 1,000 to 3,000 lb. are available for making small castings, especially in high-alloy steels with low carbon. Castings for aircraft are mainly for parts of the landing gear, most of them made of chromium/molybdenum steel (1 per cent. Cr, and 0.03 per cent. Mo) and heat-treated for tensile strengths in the range of 45 to 78 tons per sq. in. Experience has shown that, besides the correct heat-treatment, the sulphur content of the low-alloy, high-tensile steels must be low, *i.e.*, 0.01 per cent.

Book Review

Guide Pratique du Trace des Piéces en Acier Moulé (Practical Guide to the Design of Steel Castings) (in French). Published by Editions Technique des Industries de la Fonderie, 12, Avenue Raphael, Paris 16.

This is the third edition of this wellknown treatise on the design of steel castings. It differs only insignificantly from the previous editions, the alterations consisting of the modification of a few paragraphs dealing with dimensional tolerances. The result is that these are now less precisely defined than in the previous editions, presumably on the grounds that the development of new moulding methods has made it difficult to lay down general rules for machining and other tolerances. The fact that a third edition of this book has been justified, twelve years after its original publication in 1948, is in itself a tribute to the enduring value of the book to all who are concerned with the design of steel castings. It is worth reminding readers that, by arrangement with the French publishers, an English translation of this book has been produced by —and is available from—the British Steel Castings Research Association at a price of 12s. 6d.

A. H. SULLY.

Mr. OTTO F. REICHNALD has been appointed managing director of Daniel Adamson & Company, Limited, engineers, London, and Dukinfield, Cheshire, in succession to Mr. J. E. ROACH who has retired from that post and from the board.

The death is announced of MAJOR J. W. ATHEY at Worthing, in which town he lived since his retirement. In about the year 1920, he founded the Fordath Engineering Company, Limited, of West Bromwich, and later saw it develop into a business of very considerable size. Before his retirement he was extremely well known throughout the foundry industry, in which he was a popular figure.

News in Brief

THE NEXT International Measurement Conference (IMEKO) is to be held from June 26 to July 1, 1961, at Budapest. An international instrument show is to be held simultaneously.

SIX ENGINEERING/STUDENT APPRENTICES employed by the English Electric Company, Limited, have been presented with diplomas on completion of their courses at Loughborough College of Technology.

MR. T. H. COOK, B.SC., who was recently appointed chief applications engineer for the Morgan Crucible Company, Limited, Norton Works, Worcestershire, is to attend a congress in New Delhi in November.

CHASESIDE ENGINEERING COMPANY, LIMITED, announce that from August 1, all service matters relating to Lancashire and Yorkshire will be dealt with from their service division, Phillip Road, Blackburn, Lancashire.

MR. HARRY WHITTAKER, a moulder, was awarded at Leeds Assizes on July 22, £625 damages and costs in respect of injuries to his left big toe sustained in 1957 when he was employed at the Colne factory of British Thomson-Houston Company, Limited.

A NEW COMPANY, D. A. Stuart Oil Company (G.B.), Limited, has been formed as a wholly owned subsidiary of the Amber group of companies. It has been set up to market in this country the products of D. A. Stuart Oil Company, Limited of Chicago and Toronto.

THE LEITH-OWNED TANKER, Southern Garden, which has been laid up for the past two months, is to be broken up at the Firth of Forth yard of Thomas W. Ward, Limited, at Inverkeithing. The vessel is of 10,763 gross tons and was owned by the South Georgia Company, Limited, and managed by C. Salvesen & Company, Leith.

CAMBRIDGE INSTRUMENT COMPANY, LIMITED, Cambridge House, Grosvenor Place, London, S.W.1, announce 100 per cent. acceptance of their offer to the shareholders of Electronic Instruments, Limited, Richmond, Surrey, and the merger between the two companies has been completed. Permission has been obtained from the Stock Exchange Council to commence dealings in the new shares issued by the Cambridge Instrument Company.

BUYERS came from as far afield as Scotland and the south of England to attend the closing-down sale of equipment from the foundry and heavy engineering departments of Brown's Foundry Company, Limited, Nottingham Road, Derby, on July 18. Among the 750 lots offered by auction were 10 tons of nuts and bolts, three heavy overhead cranes, large lathes and foundry ladles. Prices included £300 for a 7-ton travelling crane, £96 for a metal spraying plant, and £84 for a metal band-sawing machine.

WM. DENNY & BROS., LIMITED, Dumbarton, have secured a contract to build a railway ferry for New Zealand valued at £1,800,000. The new order—which means steady employment in the Denny yards for the next two years—has been won in face of keen competition from Australian and Japanese firms. The new vessel will be operated by the Cook Strait Railway Company between New Zealand's North and South Islands. The vessel's diesel-engine propelling machinery will be supplied by the English Electric Company, Limited.

TO FURTHER THE DEVELOPMENT of Southern Rhodesia's growing steel centre, Que Que, a joint group, comprised of the Town Council, local members of Parliament and representatives of mining and industry, has been formed. It intends pressing the Government for: the establishment of Que Que as the mining headquarters for Southern Rhodesia; Government metallurgical laboratories; a technical school at Redcliff 11 miles away to serve the Midlands area of Southern Rhodesia, and the establishment of more Government departments in the town.

WITH THE OBJECT of continuing to remain in the forefront of scientific research and technical advance in iron and steel manufacture, the United Steel Companies, Limited, are to offer up to 10 university scholarships each year, tenable at any university in the United Kingdom. Each scholarship will be worth £500 per annum and its value will not be affected by parental income. Booklets and application forms are now available on request and enquiries should be addressed to University Scholarships, United Steel Companies, Limited, The Mount, Broomhill, Sheffield, 10.

RUSTON & HORNSBY, LIMITED, Lincoln, released on July 21, news of a new diesel locomotive of 275 h.p. of which the prototype has covered 3,000 miles in intensive tests in steel works, coalfields and iron-ore mines. Nine of the shunting engines are already on the assembly line, eight are destined for a steel works in Portugal, and the other will go to another company in the same country. The makers say the engine is so easy to operate that a girl can drive it, and it could have an important part in the new export drive just launched by Mr. Macmillan. "We hope for world-wide interest in it," it was said.

JOSHUA HINDLE & COMPANY, LIMITED, valve-makers, Leeds, have secured a contract worth nearly £100,000 for the supply of special leak-proof valve equipment for installation at an oil-tanker terminus at Avonmouth, near Bristol. The special valves are being used because of fire risk. The installation will handle crude oil from the Persian Gulf and have separate supply lines for each of the big petrol companies. Delivery of the contract, which was won in competition with British and American manufacturers, will start in March. The firm will be engaged for 12 to 18 months in supplying the equipment.

DURING THE LAST YEAR the Rhodesian Iron & Steel Company, Limited introduced a number of new products including fencing standards and droppers, window sections and 20-lb. rails. Now it is reported by Barclays Bank D.C.O. that it is hoped to introduce 30-lb. rails later this year. Another development expected later this year is that the new blooming mill and soaking pits, No. 3 blast furnace, sinter plant and ancillary equipment, new turbo blowers and turbo alternator will all be brought into operation. The Bank adds that the new sheet mill should be ready for use early in 1961, when production of light-plate, black and galvanized sheets should commence.

THE NORTHERN COUNTIES TECHNICAL EXAMINATIONS COUNCIL issued a report on July 21 on the progress of the scheme, introduced two years ago, of examinations for secondary modern schools, leading to the award of the Northern Counties School Certificate. It had been hoped that the scheme would provide "a worthwhile certificate to modern school leavers, and employers with evidence of attainment." This purpose is being fulfilled. The report states that when the scheme was first introduced 179 schools entered 2,506 candidates; this year 289 schools have entered 4,238 candidates; 1,400 teachers have already indicated that they will attend the first teachers' conference arranged by the Council, which will discuss the scheme, on September 10. The scheme operates throughout Northumberland and Durham, Cumberland, Westmoreland and the North and East Ridings of Yorkshire.

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The photograph below shows one of eight matched Baker Perkins units chosen to provide all the mixing requirements for an automotive grey iron foundry in the U.S.A. A strong line of five B-P (150 tons per hour) 5A Continuous Moulding Sand Mullers delivers consistently uniform sand into the moulding shop.
Behind them a B-P Core Paste Mixer and a B-P Core Wash Mixer ensure excellent core surfaces. Centre of the team is the B-P Refractory Clay Mixer for lining ladles and cupolas.
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Raw Material Markets

Iron and Steel

Holidays are now considerably curtailing outputs of castings at the ironfoundries, and in the Birmingham and South Staffordshire areas in particular production is practically at a standstill until next Monday, following the closure of the majority of foundries for the annual holiday. The only labour engaged is that employed carrying out necessary repairs to plant and cupolas, and alterations or additions to structures where required. Consumers of castings will not be unduly inconvenienced by the suspension in supplies as delivery schedules are generally up to date and in addition many of them will also be taking their holidays during the same period.

There is also a general suspension during the holiday period in deliveries of raw materials, including pig iron, coke, and scrap as stocks on hand at most establishments are adequate for resumption of work and plentiful supplies are available to satisfy additional demands. Overall production of all grades of foundry irons and hematite are more than adequate to satisfy requirements, and during the holiday period at the foundries increased tonnages will be placed into stock. Apart from some special grades the tonnages arising of cast-iron and steel scrap are sufficient to satisfy the call for supplies, and foundry and furnace coke are also adequately available.

The general trend of business at the ironfoundries shows little change. Those producing high-quality castings continue the most favourably placed, and most of these foundries will be able to maintain their high production level when they restart. The majority of the light foundries have capacity available for a much larger volume of work than is at present forthcoming, and more business is also required by the jobbing and textile foundries.

Many of the re-rollers are closed for holidays during this week and next and at many of the mills repairs to plant are being carried out during the standstill. Demands for all their products are maintained and satisfactory order-books assure them of a continuity of production at recent levels for sometime ahead. Only the shortage of suitable labour prevents them from improving on their outputs.

The re-rollers are well provided with steel semis, and most of them carry good stocks. Adequate quantities are available from home steelworks to implement current orders, which do not take up fully the tonnage on offer, and there is a slackening in demand for arisings at the steelworks of defectives and crops.

Non-ferrous Metals

Despite the unsettled position in the Congo and in Southern Rhodesia, the copper market in London has remained steady. However, doubts about the outcome of the disturbances in both countries and anxieties as to whether or not Union Miniere's operations are back to normal have sustained the market. Doubts, also, about the uninterrupted flow of supplies of copper from Africa have been a major factor in prompting the US Department of Commerce to relax its previous regulation requiring that exporters of copper should give the name of the ultimate user before being granted an export licence.

The market on both sides of the Atlantic has been affected by the holiday period and the outlook in London is still being judged on reports from Africa. In the US the market continues quiet with the price structure unchanged at 33 cents a pound for both producers and custom smelters. Elsewhere, no further reports have been made available on the discussions between Annaconda and representatives of the Chuquicamata mineworkers over the renewal of the labour contract, due to expire at the end of October.

Tin has been affected by the holiday market in London and in New York, but the market continues steady in Singapore. The feature of the London market is the persistent strength of a three months' metal which resulted in the appearance of a premium at the end of last week. The outlook in London is still good, although demand in the US has settled down to routine buying. Nevertheless, US consumption in May last increased by 4 per cent. and stocks of metal dropped 725 tons to 36,025 tons. In the US the price is fluctuating slightly below $1.05 cents a pound. The increased US demand has pushed the Singapore price up to its highest level for over three years.

Lead has shown a slight improvement in London although basically the market is quiet on both sides of the Atlantic with the US price unchanged at 12 cents a pound. Zinc continues on a routine demand basis in both London and New York, where the price is unchanged at 13 cents a pound.

Company News

RHEOSTATIC COMPANY, LIMITED—A merger has been proposed by Elliott-Automation, Limited, which intends to make an offer for the £150,000 preference and £985,600 ordinary capital.

SHEEPBRIDGE ENGINEERING, LIMITED—Final dividend of 10 per cent. makes 15 per cent. for the year ended March 31, 1960, compared with the equivalent of 12 per cent. Group net profit rose from £409,973 to £562,254, after tax of £467,284 (£390,406).

EFCO, LIMITED (formerly the Electric Furnace Company, Limited)—Final dividend of 15 (12½) per cent. makes 20 (17½) per cent. for the year ended March 31, 1960. Group net profit was £152,890 (£156,061), after tax of £136,991 (£143,816).

SIEBE, GORMAN & COMPANY, LIMITED—In the formal offer for the ordinary capital by the Fairey Company, Limited, it is disclosed that sales of Siebe, Gorman in the six months to June 30, 1960, rose by 7½ per cent. over the previous year's level.

N. HINGLEY & SONS, LIMITED, ironmasters, chain, cable, and anchor makers, of Dudley (Worcs)—In addition to maintaining the dividend at 12½ per cent. a special dividend of 5 per cent. (nil), not subject to tax, is being paid out of surplus on realization of trade investments.

VOKES, LIMITED, filtration and silencing engineers, of Guildford (Surrey)—A final dividend of 10 per cent. and a bonus of 3 per cent., makes 18½ per cent. for the year to March 31, 1960, compared with a forecast of 12½ per cent., the rate paid for the previous nine months' period, adjusting for the 100 per cent. capitalization. A one-for-five scrip issue of £204,000 new ordinary shares is proposed.

METAL CLOSURES, LIMITED, West Bromwich (Staffs)—The board has agreed to acquire all the issued capital of Ideal Capsules, Limited, in exchange for 583,333 ordinary 5s. shares of Metal Closures. The company is also to increase its holding in a subsidiary, Metal Closures Properties S.A. (Pty), Limited, by the purchase of all the 150,000 5 per cent. £1 preference shares and a further 25,003 £1 ordinary shares in exchange for £12,750 cash and 83,333 ordinary shares of Metal Closures respectively.

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Current Prices of Iron, Steel, and Non-ferrous Metals

(Delivered unless otherwise stated)

August 3, 1960

PIG-IRON

Foundry Iron.—No. 3 IRON, CLASS 2, 10-ton lots or over: Middlesbrough, £21 6s. 0d.; Birmingham, £20 18s. 3d.

Low-phosphorus Iron.—Over 0.10 to 0.40 per cent. P, 10-ton lots or over, £23 5s. 0d., delivered Birmingham, £23 10s. 0d., delivered Grangemouth.

Cylinder and Refined Irons.—North Zone, £25 6s. 6d.; South Zone, £25 9s. 0d.

Refined Malleable.—P. 0.10 per cent. max.: North Zone, £26 6d. 6d.; South Zone, £26 9s. 0d.

Hematite.—Si up to 2 per cent., S. & P. over 0.03 to 0.05 per cent., 10-ton lots or over; N.-E. of England (local iron), £23 19s. 0d.; Scotland (Scotch iron), Zone S.1, £24 5s. 6d.; Sheffield, £25 7s. 6d.; Birmingham, £25 14s. 0d.; Wales (Welsh iron), £23 19s. 0d.

Basic Pig-iron.—£20 3s. 0d., delivered Staffs, Derbyshire, Notts, Lincs, Rutland, Northants, and Leicestershire in 10-ton lots or over.

FERRO-ALLOYS

(Per ton unless otherwise stated, delivered)

Ferro-Silicon (6-ton lots and over).—45 per cent. Si, £42 10s. 0d. to £44 10s. 0d., scale 15s. 0d. per unit, lumpy; 75 per cent. Si, £57 15s. 0d. to £61 10s. 0d., scale 15s. 0d. per unit, lumpy.

Ferro-Vanadium.—50/60 per cent., 20s. 6d. per lb. of V.

Ferro-molybdenum.—65/70 per cent., carbon-free, 12s. 10d. per lb. of Mo.

Ferro-titanium.—20/25 per cent., 2-3 per cent. Cu, £250 0s. 0d.; 38/40 per cent., commercially carbon-free, £287 0s. 0d.

Ferro-tungsten.—80/85 per cent., 12s. 1d. per lb. of W.

Tungsten Metal Powder.—98/99 per cent., 15s. 1d. per lb. of W.

Ferro-chrome (6-ton lots and over, lumpy).—4/6 per cent. C, £80 10s. 0d. to £84 10s. 0d., basis 60 per cent. Cr, scale 27s. 0d. to 28s. 6d. per unit; over 6 per cent. C, £79 0s. 0d. to £82 £0s. 0d., basis 60 per cent. Cr, scale, 27s. 0d. to 28s. 6d. per unit; 2 per cent. C,* 1s. 8d. to 1s. 11d. per lb. Cr; 1 per cent. C,* 1s. 8½d. to 1s. 11½d. per lb. Cr; 0.15 per cent. C,* 1s. 9½d. to 2s. 0½d. per lb. Cr; 0.10 per cent. C,* 1s. 9¾d. to 2s. 0¾d. per lb. Cr; 0.06 per cent. C,* 1s. 10¾d. to 2s. 1d. per lb. Cr.

Metallic Chromium.—98/99 per cent., 6s. 10d. per lb.

Metallic Manganese.—94/96 per cent., carbon-free, £275 0s. 0d.; 96/98 per cent., £285 0s. 0d.

Ferro-columbium.—65/67 per cent., Cb + Ta, 19s. 9d. per lb., Cb + Ta.

Ferro-manganese (Standard).—78 per cent., £61 10s. 0d.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms, and Slabs.—BASIC: Soft u.t., 100 tons & over, £31 15s. 6d.; tested, 0.08 to 0.33 per cent. C, 6 to 35 tons, £33 15s. 6d.; hard (0.41 to 0.60 per cent. C), under 10 tons, £34 17s. 0d.; silico-manganese, under 10 tons, £43 16s. 6d.; free-cutting, under 10 tons, £36 14s. 6d. SIEMENS MARTIN ACID (under 10 tons): Up to 0.25 per cent. C, £41 1s. 0d.; silico-manganese, £44 4s. 0d.

Billets, Blooms, and Slabs for Forging and for Stamping (under 10 tons).—BASIC: soft, up to 0.33 per cent. C, £38 10s. 0d.; basic, hard, over 0.41 up to 0.60 per cent. C, £39 12s. 6d.; acid, up to 0.25 per cent. C, £43 4s. 0d.

FINISHED STEEL

Heavy Plates and Sections (1 ton to 10 tons).—Ship plate (N.-E. Coast), £41 12s. 0d.; boiler plates (N.-E. Coast), £44 2s. 0d.; floor plates (N.-E. Coast), £43 10s. 0d.; angles (N.-E. Coast), £38 16s. 6d.; joists (N.-E. Coast), £38 12s. 6d.

Small Bars, Sheets, etc.—Rounds and squares, under 3 in., and flats 5 in. wide and under, untested soft basic, 50 tons and over, £39 1s. 0d.; under 10 tons to 4 tons, £40 18s. 0d.; under 4 tons to 2 tons, £41 3s. 0d.; hoop and strip, coils, 100 tons and over, £38 0s. 0d.; uncoated strip mill coils, hot rolled, under 3 mm. to 12g., 25 tons to under 50 tons, £43 16s. 0d.; black sheets (hand mill), 24g., 10 tons and over, £57 14s. 6d.; galvanized corrugated sheets, 24g., 10 tons and over, £68 5s. 0d.

Alloy Steel Bars.—1 in. dia. and up: Nickel, £67 17s. 0d.; nickel-chrome, £98 11s. 0d.; nickel-chrome-molybdenum, £111 4s. 0d., in lots of 5 tons to under 10 tons.

NON-FERROUS METALS

Copper.—Cash, £253 10s. 0d. to £253 15s. 0d.; three months, £248 5s. 0d. to £248 10s. 0d.; settlement, £253 15s. 0d.

Copper, Tubes, etc.—Solid-drawn tubes, 2s. 5d. per lb.; rods, 270s. 6d. per cwt. basis; 20 s.w.g., 305s. 6d. per cwt.

Tin.—Cash, £813 0s. 0d. to £814 0s. 0d.; three months, £813 10s. 0d. to £814 0s. 0d.; settlement, £814 0s. 0d.

Lead (Refined Pig).—First half August, £71 2s. 6d. to £71 5s. 0d.; first half November, £71 7s. 6d. to £71 10s. 0d.

Zinc.—First half August, £89 0s. 0d. to £89 2s. 6d.; first half November, £88 12s. 6d. to £88 15s. 0d.

Zinc Sheets, etc.—Sheets, 15g. and thicker, all English destinations, £126 10s. 0d.; rolled zinc (boiler plates), all English destinations, £124 5s. 0d.; zinc oxide (Red Seal), d/d buyers' premises, £105 0s. 0d.

Brass Tubes, etc.—Solid-drawn tubes, 2s. 0d. per lb.; sheets to 10 w.g., 222s. 3d. per cwt.; wire, 2s. 10½d.; rolled metal, 217s. 3d. per cwt.

Brass (Brazing).—BS1400, B3, £177; B6, £227.

Brass (High Tensile).—BS1400, HTB1, £203; HTB2, £222; HTB3, £236.

Gunmetal.—BS1400, LG2, £225; LG3, £235; G1, ½%, £290; G1, 1%, £277.

Phosphor Bronze.—BS1400, PB1 (AID released), £320; BS1400, 90/10/1, £304.

Leaded Phosphor Bronze.—BS1400, LPB1, £245.

Phosphor Bronze Strip, etc.—Strip, 314s. 0d. per cwt.; wire, 4s. 3⅝d. per lb.; rods, 3s. 6¼d.; tubes, 3s. 6½d.; chill cast bars, solids 3s. 6d.; cored 3s. 7d (CHARLES CLIFFORD, LIMITED).

Nickel Silver, etc.—Rolled metal, 3 in. to 9 in. wide × 0.056, 3s. 11¾d. per lb.; round wire, 10g. in coils (10 per cent.), 4s. 4¾d.; special quality turning rod, 10 per cent., ½ in. dia., in straight lengths, 4s. 3¾d. All prices are net.

Other Metals.—Magnesium, ingots, 2s. 2½d. to 2s. 3d. per lb.; Antimony, English, 99 per cent., £190 0s. 0d. Quicksilver, ex-warehouse, £70 0s. 0d. to £70 10s. 0d. Nickel, £600 0s. 0d. Aluminium, ingots, £186 0s. 0d.; aluminium bronze (BS1400), AB1, £262, AB2, £270.

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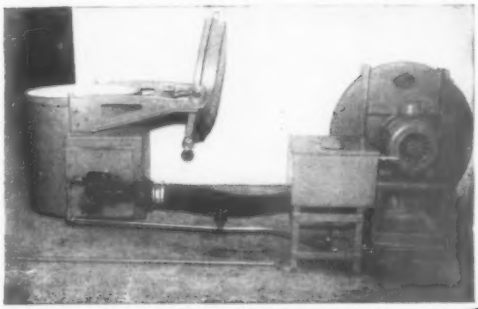

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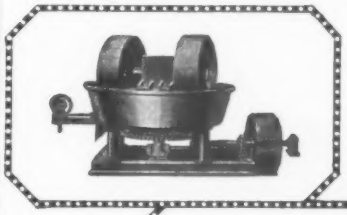

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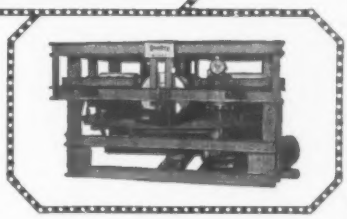

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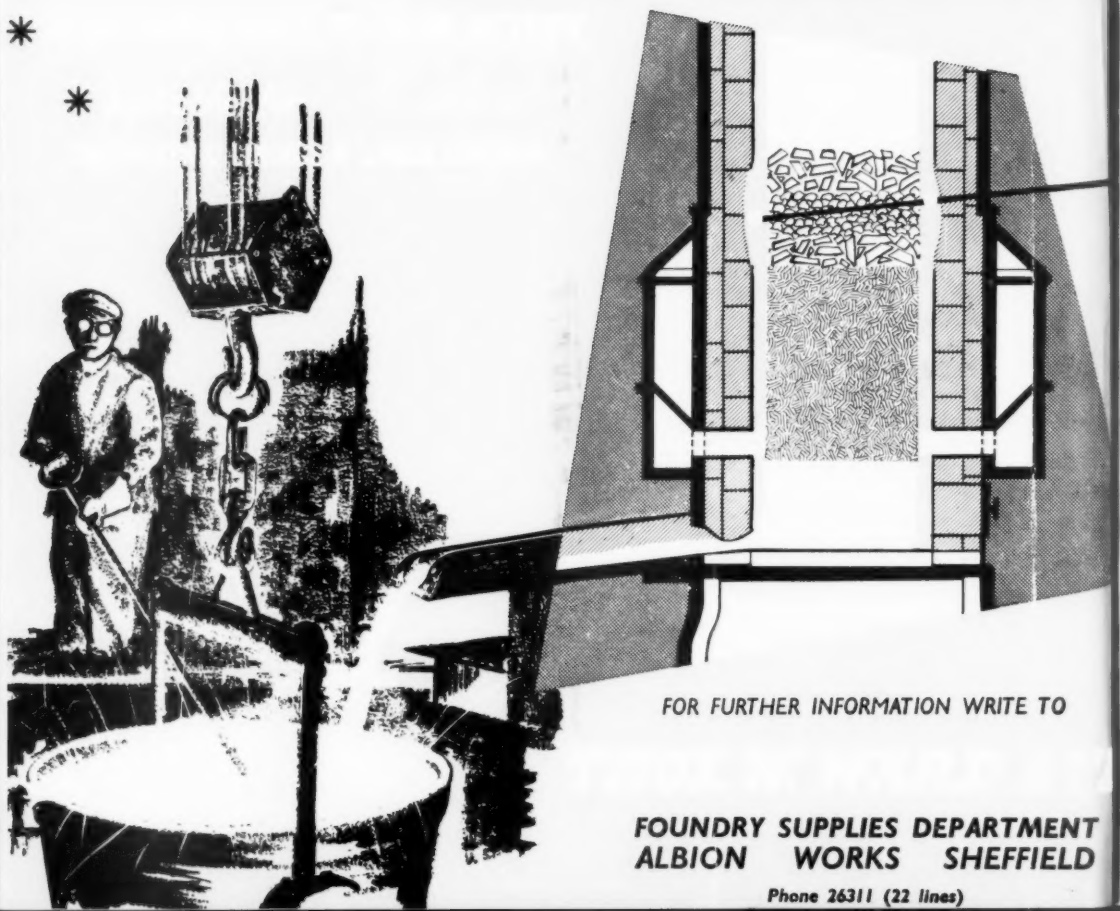

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